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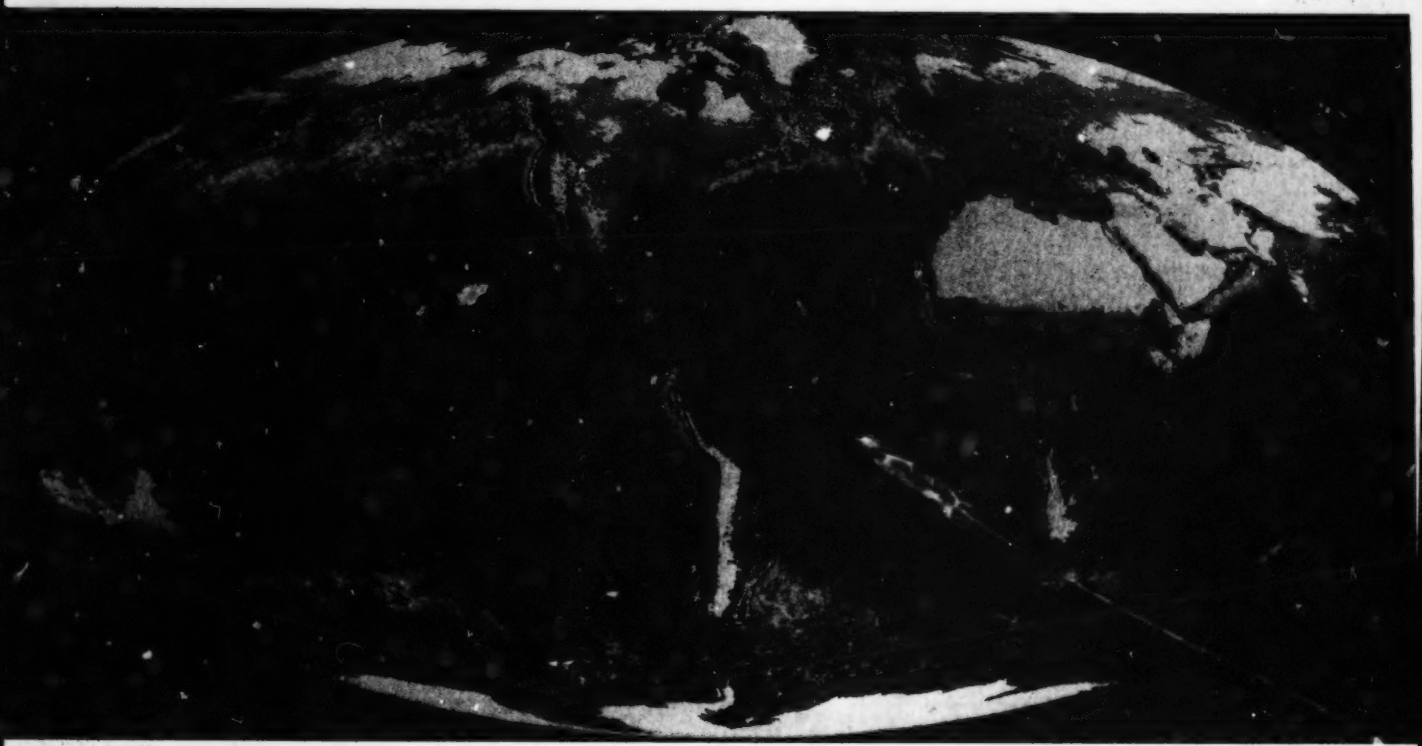

Selected Papers on Remote Sensing, Satellite Communications and Space Science 1994

United Nations

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United Nations Programme on Space Applications

Selected Papers on Remote Sensing,
Satellite Communications and Space Science
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INTRODUCTION

In the span of the past decade, space technology has become an integral part of the everyday lives of many of the world's inhabitants. Virtually all countries of the world rely on satellites for some of their communications needs, for television broadcasting and for meteorological forecasting. New applications of space technology are constantly being discovered and spin-offs from space technologies have led to advancements in such diverse fields as medicine, materials sciences and computers. Nevertheless, the high cost of participating in space activities has hindered the ability of many countries, particularly the developing countries, to fully take advantage of the many practical benefits that space technology offers for economic and social development.

The United Nations, through the Office for Outer Space Affairs, has therefore focused its efforts on expanding developing country access to the practical applications of space technology. Through the Programme on Space Applications, the Office annually conducts 8 - 10 workshops, seminars and training courses which assist developing countries in the establishment of indigenous capabilities in space technologies. These activities bring together experts in various space-related fields and facilitate the exchange of information among experts and scientists from developed and developing countries. This publication, the fifth in an annual series initiated in 1989, is part of the Office's efforts to expand and encourage the international exchange of information and experience, which, along with other programmes and publications, promotes the United Nations goal of ensuring that outer space is used for exclusively peaceful purposes and for the benefit of all countries.

This publication is comprised of selected papers presented at the 1993 activities of the Programme on Space Applications that illustrate the issues related to the use of space technology for development, especially through management of natural resources and the environment, and to meet communications needs. The scope of the publication extends from a general overview of the applications of satellite communications for development, and a discussion of the particular difficulties faced by developing countries in the establishment of national space programmes to more specific areas of applications of space technologies, including the use of remote sensing for resource management in Africa and satellite meteorology for disaster warning and mitigation in the Caribbean region. Because the papers are selected from workshops, training courses and seminars held in various parts of the world, they address applications corresponding to the specific needs of the regions concerned.

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SPACE RESOURCES AND MECHANISMS FOR DEVELOPING COUNTRIES*

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In recent years space applications have become an important discipline that can be put to use to aid developing countries. Without underestimating the role of conventional techniques, it is perhaps appropriate to say that space technology has now emerged as an indispensable tool for monitoring the environment and management of natural resources on a global scale.

Scientific and technological cooperation between the developing countries and the European Community (EC) is an important and comprehensive activity which integrates scientific components with informal technology transfer and capacity building. Thus, the expansion of cooperation with the developing countries in the fields of research, technology and development, together with trade and financial assistance, constitutes one of the main components of the EC relationship with these nations.

Perhaps the most significant Community action in this area is its agreements with developing countries from Africa, the Caribbean and Asia which are enshrined in the so-called Lomé Conventions. Even during the early 1980s, when Lomé III was signed, attention was given to combating desertification. Research operations, including space data utilisation, were undertaken in the field of desertification, water resources, improvement of weather forecasting, establishment of a system for the prevention and control of forest fires and deforestation. In fact, the Convention called for a "drought and desertification control" component to be incorporated into all agricultural and rural development operations. Lomé IV, signed in December 1984, placed environmental issues at the top of a list of priorities for cooperative projects between the EC and developing countries in the African -Caribbean -Pacific (ACP) regions. Other priorities included agriculture, food security and rural development.

Emphasis on regional cooperation is a common feature of successive Lomé Conventions. In the relevant section of Lomé IV, the preservation and improvement of the environment is included in the section on regional cooperation. This should be achieved "especially through programmes to combat desertification, deforestation, erosion, coastal deterioration, marine pollution ... with a view to ensuring rational and ecologically balanced development." While the bulk of the Community's expenditure on environmental programmes

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* This paper, which was presented at the United Nations/International Astronautical Federation Symposium on "Organizing Space Activities in Developing Countries: Resources and Mechanisms," held in Graz, Austria, 15-17 October 1993, does not necessarily represent the views of the United Nations.

is channelled through credit lines devoted to the specific needs of individual countries, there are also two budget lines specifically devoted to environment-related development issues. One is being utilised for pump-priming projects, for methodological research and to improve the Commission's capacity to integrate the environment into its own activities and in particular to reinforce environmental impact assessment procedures. This budget line has received a threefold increase to ECU 26 million in 1993. These funds are also being used to cover policy development costs. The second specific budget line is for protection of tropical forests. This budget category, which was initiated in 1991 with a budget of ECU 2 million, is now funded at ECU 50 million. It is mainly used for the protection and rational management of tropical forests. This is in line with the European Community's commitment to fund international sustainable development efforts while respecting the "Statement on Forest Principles."

These components of the EC's development policy require the utilisation of space data. Currently, several projects relevant to these issues are being implemented in the African-Caribbean-Pacific regions. In addition, the Directorate-General for Development (DG-VII) provides aid for the satellite data receiving station in Maspalomas, Canary Islands, which gathers data for the African region. These activities are implemented in collaboration with the European Space Agency (ESA). The objective of the effort is to develop a reliable data set for West Africa using information from the Landsat, NOAA/AVHRR and SPOT satellite systems.

The Directorate General for External Relations (DG-I), in collaboration with ESA, also provides funding for upgrading receiving stations for data from the ERS-1 satellite system in several countries of the Association of South East Asian Nations (ASEAN). The overall objective is to develop EC-ASEAN cooperation and technology transfer in the area of remote sensing for applications to meet development and environmental needs and *inter alia* to provide a means to assess and monitor tropical forests and to manage natural resources in those countries.

The CEC, in cooperation with other European groups, is conducting several pilot projects utilising ERS-1 data for land use studies, flood monitoring, rice monitoring, coastal zone monitoring and tropical forestry in Malaysia, Indonesia, Thailand and the Philippines.

The Directorate-General for Science, Research and Development (DG-XII), through its Directorate for Cooperation with the Third Countries and International Organizations, has in place a programme for Science and Technology for Development (STD) which provides support to several European groups working in the area of tropical forestry and agricultural research using remote sensing data. In addition, the Programme for International Scientific Cooperation (ISC) is another channel for support to third countries *inter alia* in the area of environmental research. The aim is to promote the mobility of scientists between EC Member States and third countries and to involve research centres in these countries with European institutes on a cooperative basis in order to tackle scientific problems of common interest and to establish permanent links between the relevant scientific communities in

Europe and the third countries.

In October 1992, the CEC, in cooperation with the State Science and Technology Commission of China, organized a workshop in Beijing entitled "Contribution to Global Change: Biosphere-Atmosphere Interactions."

On 29 April 1993, the Council of EC Research Ministers approved a CEC statement entitled "The European Community and Space: Challenges, Opportunities and New Actions." The CEC stated its intention to intensify and expand the cost-effective use of space-derived data for implementation of Community policies of cooperation with developing countries. The CEC is currently conducting a study on "Analysis of the Constraints and Opportunities for Cost Effective Implementation of Earth Observation Techniques in Developing Countries. The objectives of the study are to: a) identify the key factors (economic, organizational, etc.) that affect the development of earth observation applications in developing countries; b) assess the relevance to these factors to similar factors in the developed countries; and c) recommend future European policies.

The European Space Agency (ESA) is also conducting a study on the utility of earth observation data in developing countries. Together with the ESA, the CEC should move towards a common European plan of action in this area. As part of this effort, the CEC and ESA co-sponsored a workshop on the "Assessment of the Potential Needs of Remote Sensing Applications in Developing Countries," held in Nairobi, Kenya from 23-27 November 1993.

I would now like to turn to the work performed at the CEC Institute for Remote Sensing Applications (IRSA) in Ispra, Italy. The development and use of remote sensing applications from satellites for the monitoring of the earth's resources and the environment has been a major goal of the Joint Research Centre (JRC) since the first Landsat data became available in the early 1970's. Since then, the research and development effort at the JRC has steadily expanded. The space application projects of IRSA which are relevant to the theme of this meeting include the following:

- monitoring of vegetation in tropical and sub-tropical regions. Some of the studies which have utilised satellite data include: tropical deforestation, biomass burning, environmental conditions in large river basins and rain fed crop production;

- monitoring of the marine environment, including coastal upwelling, ocean productivity and ocean colour research;

- studying of land degradation and desertification;

Some of the projects in the above areas which have been jointly developed in collaboration with ESA are:

- Tropical Ecosystem Environment Observations by Satellites (TREES); and

- Ocean Colour European Archive Network (OCEAN).

The European Airborne Remote Sensing Capabilities (EARSEC) programme is another joint CEC-ESA programme. While the EARSEC project is a European initiative, it nevertheless is a programme which has potentially global applications, particularly to the developing countries. The goal of EARSEC is develop a series of advanced airborne sensors to serve the scientific community, as well as the public and private sectors. The advantages of airborne remote sensing are well known. Airborne sensors can be selectively used in a flexible manner to acquire data with high spectral and spatial resolution. At present, the CEC is developing synthetic aperture radar (SAR) systems and a sophisticated imaging spectrometer. These will be used, for example, for environmental monitoring, land use, forestry and agriculture studies. Once the EARSEC systems become operational, developing countries will be able draw on this unique capability for their particular requirements.

Another CEC project that is a result of the on-going cooperation with ESA is the Centre for Earth Observation (CEO), which is a joint project of the EC and the members of the European Free Trade Association (EFTA). The goal of this project is to establish an effective network for the full exploitation of earth observation data, including those obtained by spaceborne sensors.

The necessity of implementing such a European initiative is obvious considering the staggering amount of earth observation data expected from future satellite missions. The CEC is currently studying how the project should be structured to ensure that it takes into account the requirements of the developing countries for satellite data. A feasibility study on the Centre was completed recently and a pathfinder phase was begun in January 1994, to be followed, if it is approved, by an implementation phase to extend from 1995-1998. The activities of the Centre would include gathering, processing, validation, standardisation and archiving of global environmental data.

It is evident that the evolving commitments of the EC towards the protection of the environment and the Earth's resources require reliable and consistent earth observation data. The EC is a signatory of the Framework Convention on Climate Change and as a follow-up to the United Nations Conference on Environment and Development (UNCED), is committed, *inter alia*, to actively participate in the negotiations for the elaboration of an international convention on desertification.

In December 1992, the Council of EC Environment Ministers adopted a resolution on the new Community policy on the environment and sustainable development. The resolution, entitled "Towards Sustainability," concluded that this fifth Environment Action Programme was "an appropriate point of departure for the implementation of Agenda 21 by the Community and Members States."

In May 1993, the Development Council of Ministers, taking into account the forthcoming first meeting of the United Nations Commission on Sustainable Development (New York, 14-25 June 1993) confirmed that the EC and its Member States would provide an initial tranche of ECU 600 million in 1993 for specific projects and programmes in key Agenda 21 sectors. This represented the EC's first contribution to the ECU 3 Billion pledge undertaken by the Community and its Member States at Rio. This year the contribution will be committed to, among others, the following areas: a) desertification, b) forests, and c) water resources. Obviously space data will be used for different specific projects related to these areas.

A new element of the CEC's activities to assist developing countries in the field of global change studies is the recently launched project entitled "European Network for Research In Global Change" (ENRICH).

The goal of the ENRICH programme is to bring together the critical mass of resources and capabilities of industrialised and developing countries and to provide a logistical basis for managing collaboration among the involved countries and international research institutes. The overall objective of the programme is to provide a major European contribution to international global change research *inter alia* in response to the outcome of UNCED, the Intergovernmental Meeting of World Climate Programmes (IGM-WCP) and the OECD's Mega-Science Forum meeting on global change.

The CEC has proposed that the ENRICH effort be used to support public policy objectives by collecting and analysing relevant information, promoting cooperation, education, training and dissemination of information. ENRICH would also promote endogenous research capabilities in developing countries, mainly, but not exclusively, in Africa, the Mediterranean basin, Central and Eastern Europe. This network, which will obviously involve the use of space observation, will be built largely on the facilities and capabilities of existing institutions and will respond to the scientific agendas of ongoing global change programmes such as the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP). ENRICH also aims to ensure coherence with similar initiatives in other parts of the world, such as the Inter-American Institute and, if the concept matures, the Asia-Pacific Network for Global Change Research.

ENRICH is based on the concept of a decentralised network designed to create the necessary relationship between the EC mechanisms supporting global change research and relevant national and international programmes.

Thus, a key goal of ENRICH is to focus on research, relying essentially on the existing capabilities and facilities in order to respond to the scientific agendas of ongoing global change research programmes. ENRICH should be an important structure involving the governments of the EC and the European Free Trade Association (EFTA) and should also provide a sound scientific and technological input to EC policy decisions.

In summary, the CEC is firmly committed to providing full support to issues such as scientific and technological cooperation and capacity building in developing countries. In the spirit of Agenda 21 and as a follow up to UNCED, the CEC will seek global partners. Such international cooperation is a prerequisite to understanding and solving the problems of the Earth's deteriorating environment.

SPACE TECHNOLOGY, HYDROLOGY, AND EDUCATION*

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INTRODUCTION

Someone recently said "Our children constitute 25 per cent of our population and 100 per cent of our future." In the past, the key to the successful development of any economically and politically independent nation has been the early and continuous formal education of its children. In today's world, however, the margin of superiority belongs to those nations that couple such an education with excellence in technological literacy. How can we accomplish both, and simultaneously address still another issue of local, regional, national, and even global importance -- water?

The answer can be found in space technology and hydrology education. The study of the four principal components of the hydrologic cycle -- evapo-transpiration, condensation, precipitation, and groundwater storage and runoff -- necessarily encompass studies of geography, geology, weather and climate, math, physics, and a host of other topical classroom subjects. The introduction of a low cost weather satellite ground receiving system in the pre-college classroom enhances and enriches the academic atmosphere by allowing students to acquire real-time imagery and to observe and interpret those processes that affect the hydrologic cycle. Such an activity is not limited by the economic status or linguistic capabilities of the student; nor is it impeded by political boundaries. And in the process of using weather satellite observations to study the hydrologic cycle, students also are exposed to other forms of space technology applications in such diverse areas as communications, livestock management, fishing, dam construction, forest resources monitoring, search and rescue via satellite, and global change phenomena

This is not a hypothetical scenario. The use of weather satellite receiving systems in the classroom to stimulate and motivate academic achievements and enhance the student learning process is the fastest growing application of these satellites in the world today. Furthermore, using space technology to study water availability, distribution, quality, and usage in schools is a learning experience that extends far beyond classroom walls; space technology and hydrology education begins at the village well or cistern, and expands to include responsible stewardship for the ponds, streams, rivers, and oceans upon which all creatures depend; management of the precious rainfall that helps sustain life on Earth; and the need for sustainable water resources development and environmental evaluation and

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* This paper, which was presented at the United Nations Regional Conference on Space Technology for Sustainable Development in Africa, held in Dakar, Senegal, from 25-29 October 1993, does not necessarily reflect the views of the United Nations.

assessment in Africa and elsewhere.

SPACE TECHNOLOGY, HYDROLOGY, AND EDUCATION

Space technology, hydrology, and education are being merged in a proposal being submitted to the United States National Science Foundation in April 1994. The proposal is called "Project HydroSpace." The proposers are the Johns Hopkins University in Baltimore, Maryland, known internationally for its contributions to medical science, and Oklahoma University in Norman, Oklahoma, the home of the state's Climatological Survey office and site of the new NOAA National Weather Service NEXRAD radar system. The tools that will be used in Project HydroSpace are rain gauges and low cost weather satellite ground receiving stations that will be provided to selected pre-college educational institutions in Maryland, Oklahoma, and the South Pacific. South Pacific schools and Oklahoma schools will communicate with each other through the Peacesat satellite, while Oklahoma and Maryland schools will communicate through Internet.

The concept of Project HydroSpace involves the study of water and space technology -- hence the name "HydroSpace." It involves students, mainly at the middle school level, but also at the elementary and high school levels. Is this a concept that could be transported to Africa? Is this a role that space technology can play in the social and economic development of Africa? It certainly is a viable technique for developing indigenous capabilities in the use of space technology at the local level, and it addresses a centuries-old concern of all Africans -- water.

Intellectual Africans share a concern for population growth and the demands this growth is placing on water for public consumption, agriculture, and industry on this continent. Yet according to recent surveys by the Sub-Saharan Hydrologic Project and for the WMO/UNESCO report on Water Resources Assessment, there has been a serious decline in the collection and management of hydrometeorological data in many African countries. There are many reasons given for this, of course, among them the lack of money, lack of resources, and lack of personnel. The net result is that information needed for sustainable water resources development in Africa is essentially unavailable. If such data are not compiled, what will be the outcome?

Today, governments and international agencies, both inside and outside Africa, are working together in an effort to compile hydrometeorological data to develop and manage this continent's water resources. But with the world's population predicted to double from 5 billion to 10 billion people within the next 40 years, many governments and agencies may become less concerned with Africa's water problems and more concerned with another, more ominous problem in their own back yards -- the problem of a diminishing fresh water supply.

Less than one per cent of the world's water supply is available for human consumption, for agriculture, and for industry. For centuries, even millennia, no one ever gave thought to the idea that Planet Earth might some day run out of fresh water. In January 1993, Gilbert

Grosvenor, President of the prestigious National Geographical Society, helped call attention to this fact by announcing the beginning of a new multi-year programme titled "Geography of Fresh Water; a New Society Initiative." Grosvenor likens the energy crisis of the 1970's to a pending global crisis in water, and he notes that, like oil, fresh water is not a renewable resource.

There is a major international programme getting underway that also addresses the issue of water, but in a different way. The Global Change Research Programme is a multi-million dollar, multi-national, 15-20 year programme to collect information about regional and planetary changes that have and are occurring in the atmosphere, oceans, and on land. This programme places the study of climate and the hydrologic cycle at the top of their list of seven science priorities. The primary technology, without which such an undertaking could not even have been considered, is space technology.

Since 1969, educators in schools and colleges in the United States, the United Kingdom, and elsewhere have been learning how to infuse weather satellite direct readout image reception as an educational resource. Over 30 formal summer training programmes have been held in the U.S. just within the past four years, to help teachers learn how to use this technology in conventional classroom studies. About 10 years ago, two high schools in South Africa built their own weather satellite receiving station with help from the African Amateur Radio Relay League. And within the past year, a commercially built system was placed in a school in Zimbabwe.

Project HydroSpace builds on the curriculum and lesson plans that have been developed in several countries by teachers over the past 30 years to use weather satellite direct readout reception in the classroom. It merges this aerospace technology with the need to call attention to the world's diminishing supply of fresh water. And it does it in such a way that students, regardless of language barriers, economic or social levels, or academic achievement levels, can be participants.

The project begins by asking students to compare rainfall with various cloud forms seen in satellite imagery. In the course of looking at satellite images, the students have to learn geography to know where they are looking, before they can say what they are looking at! This introduces the concept of time zones, and latitudes and longitudes. Students have to use math to extrapolate times and positions when the satellite will be overhead.

Image interpretation also requires recognizing changing land patterns in areas of urban development, or deforestation, in order to study evapo-transpiration. More advanced students will be taught to apply physics and chemistry to understand the principles of cloud formation, causes of acid rain, and the impact of nitrates and pesticides on water quality as a result of precipitation runoff. Watersheds and the engineering of dams and reservoirs, including the political and humanitarian ramifications of these activities, will be taught. The learning process also includes computer manipulations, from the simple to the complex.

The entire programme is loosely disguised as a study of all the components of the hydrologic cycle, mixing space observations with in situ water measurements. And it includes studies adaptable to over 20 classroom topics and disciplines through all pre-college grades.

This programme was not devised by accident. It takes into account the fact that the global change research programme lists the study of climate and the hydrologic cycle as the highest science priority. It focuses on concerns for water, and it endeavours to address a national decline in math and science literacy. In Africa, the course content of Project HydroSpace could be linked to a "World Hydrological Cycle Observing System" (WHYCOS) being proposed by the World Meteorological Organization (WMO).

The WMO is proposing that WHYCOS be established to improve the availability and timeliness of hydrological and related data for planning and development purposes in Africa and elsewhere. A key component of the WHYCOS programme is to establish a network of hydrologic platforms that would telemeter their data to satellites, then back to selected ground sites for processing.

To succeed, WHYCOS must be a long-term effort. Funding, of course, is essential. But other, more subtle factors also will play a key role in the success of WHYCOS. Government officials, business leaders, and especially the general public must understand the importance of developing sustainable water resources measurement systems. In addition, a technologically-literate workforce must exist to sustain such an effort. How can government officials, business leaders, and the public be "sensitized" to the objectives of WHYCOS, and how can we insure a technology-literate workforce? Popular and academic education is the best solution, and ultimately, the only solution.

To begin the educational process, we might consider merging the Project HydroSpace concept with WHYCOS. Engage students in making rainfall measurements by providing them with instructions, and materials if necessary, for constructing simple but reliable rain gauges. Have them send their records, by mail if necessary, to a reliable source for quality control and integration with measurements made by other students. (Students have proved to be very capable resources for making observations related to national programmes in times past. A student soil classification programme instituted in the United Kingdom in the 1930's is credited with helping it raise three times as much food during World War II as it had been raising prior to the war.)

Reward those schools that continually and reliably submit rainfall records by placing a low cost weather satellite station in the school. (Such stations are available from a score of companies). Accompany this "reward", or perhaps even precede it, with curriculum guidelines and materials being created for students that will participate in the Johns Hopkins University-Oklahoma University Project HydroSpace. This material relates cloud formations as seen from space with rainfall that is measured (in situ) on the ground -- a simple and exciting learning exercise in which even elementary students can participate.

Descriptions of the hydrologic cycle appear early in school textbooks. These descriptions become more detailed in advanced middle and high school textbooks. Coupling text descriptions with direct readout of satellite imagery in the schools creates an authentic, "hands-on" learning experience in which students begin to see the importance of the hydrologic cycle and water distribution in terms of their own and neighbouring geography, topography, climatology, and land use or abuse. Even in areas where rainfall (and therefore clouds) is sparse or highly seasonal, students viewing their expanded environment through the use of satellite imagery will see for themselves how the variability of rainfall impacts agriculture, transportation, power generation, and populations. Economic, scientific, ecological, sociological and humanitarian issues related to water rights, water quality, distribution, availability, storage, and runoff become far more evident and real when students are involved in applying previously learned skills to such innovative experiences as taking rainfall measurements and simultaneously interpreting weather satellite observations.

Consider what this learning approach already is bringing to classrooms in many countries: enhanced computer literacy; a knowledge of, and the ability to apply, space technologies that include not just remote sensing from weather or earth resources satellites, but communications and research satellites as well; cross-disciplinary and multidisciplinary learning; higher academic achievement levels; and new job skills and career opportunities.

The WHYCOS proposal notes that the hydrologic cycle is a fundamental element in the global climate system. Project HydroSpace similarly notes and emphasizes the climatic significance of studying evapo-transpiration, condensation, precipitation, and groundwater storage and runoff -- the four components of the hydrologic cycle. Combining a HydroSpace-type educational component with WHYCOS could help underscore for students, and adults, the necessity for the type of measurements and observations needed in order for WHYCOS to accomplish its aims and objectives. It can, in fact, involve many students and schools in every country in Africa in an economical, logistically feasible, and at the same time essential and realistic programme, to improve the availability and timeliness of hydrological and related data for planning and development purposes.

CONCLUSIONS

There is no disputing the fact that the quality of life in any country, on any continent, is almost entirely equated with education. Better educated peoples generally enjoy better standards of living than their less educated counterparts. They make more money, and therefore have more to spend on goods, commodities, services, and cultural pursuits. Better educated people also tend to be more supportive of their national governments, changing their leaders through peaceful means, thus creating a more stable environment for social growth and economic development.

How does this observation relate to the objectives of this Regional Conference on Space Technology for Sustainable Development in Africa? Two key objectives of this conference are to identify the role of space technology in the social and economic

development of Africa, and methods for developing indigenous capabilities in space technology at the local level.

Thus, early and continuous education is the common denominator. The use of weather satellite direct readout resources in the classroom is a proven, definable role for space technology in social and economic development through enhanced education. It is also an economically feasible role, since the costs of implementing this technology on a national or even continental scale can be measured in thousands rather than millions of dollars. It also is a most logical and practical method for developing indigenous capabilities in space technology at the local level. Coupling this learning experience with studies of the hydrologic cycle has the additional benefit of emphasizing our growing national, regional, and global concerns for fresh water, and the need to observe, measure, and utilize our water resources more wisely. By integrating space technology, hydrology, and education, we see the application of that old adage -- learn by doing!!

ESTABLISHING THE ORGANIZATIONAL AND INSTITUTIONAL INFRASTRUCTURE FOR A NATIONAL SPACE PROGRAMME*

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INTRODUCTION

Science and technology have improved the general quality of life all over the world. More people are better clothed, many epidemics have been eradicated or contained, the average lifespan has increased, and there is a more consistent food supply. There have also been improvements in transport, communication and the material quality of life. However, the bulk of humanity, especially in the developing countries, still lives in poverty and their needs have remained unfulfilled. Such a situation has not arisen because of the failure of science and technology but it has a lot to do with the social ethos, economic policies, administrative systems and the capacity of governments to deliver the goods.

Scientific and technological progress is intimately related to the economic and social development of a country. A planned economy must provide for the profitable utilisation of material resources and manpower and the application to the fullest extent of the latest scientific and technological inventions and discoveries which are of economic and sociological interest. Recognising that science and technology alone could solve the problems of hunger and poverty, the lack of sanitation, illiteracy, superstition and deadening customs and traditions, of vast resources running to waste, India adopted, as far back as in 1958, a scientific policy resolution which emphasised the following objectives:

1. the promotion, by all appropriate means, of the cultivation of science and scientific research in all its aspects, pure, applied and educational; and

2. securing for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The adoption of this resolution on scientific policy has enabled the country to become self-sufficient in food production through a green revolution during the 1960s, to establish a strong industrial base and to develop indigenous scientific and technical manpower. Today the country is able to fully exploit the potential of advanced technologies for establishing a

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* This paper, which was presented at the United Nations/International Astronautical Federation Workshop on Organizing Space Activities in Developing Countries: Resources and Mechanisms, held in Graz, Austria, 15-17 October 1993, does not necessarily reflect the views of the United Nations.

viable and self-supporting infrastructure, and this has resulted in the development of a scientific temper in the country's approach to shaping the life of the people. For those policy makers and administrators, especially of the developing countries, who probably consider that investment in science and technology is a waste and does not contribute directly to progress, India's strides in the application of science and technology for national development could serve as an eye opener.

Of all the new frontiers of science and technology, space technology stands out as one of the most attractive ones, and one which could emphatically prove its utility as a tool for national development. Of course, for thousands of years men have sought their future in the starry sky. With the launching of sputnik in 1957, the world saw the birth of a new "Space Age" with immense potential. To the scientist, space techniques have provided a powerful new tool for exploring the universe, providing new windows and eyes to explore what was previously inaccessible. Space science and technology has thus fulfilled the dream of humanity which was beautifully paraphrased by Socrates around 400 BC: "We, who inhabit the Earth, dwell like frogs at the bottom of a pool. Only if man could rise above the summit of air, could he behold the true Earth, the world in which we live." Space technology and its innumerable spinoffs has transformed many of the developed countries around the world. But the greatest challenge for the developing countries is to adopt, plan and select the most appropriate space technologies and come out of the darkness created by ignorance, poor management of resources, lack of access to technology and the constant threats of natural disasters.

PROBLEMS OF DEVELOPING COUNTRIES

Nearly 75 per cent the global population lives in developing countries. These countries, in turn, geographically occupy 63 per cent of the world's total available land area. However, the combined gross national product (GNP) of these countries barely constitutes 20 per cent of the world's GNP. It is estimated that for every one per cent increase in population growth, a corresponding increase in GNP of at least 2.5 per cent is required for sustainable living. Though it is an established fact that the application of the best in modern technology can only ameliorate the living standards of people, most developing countries spend less than one-half of one per cent of their GNP on research and development (see tables 1a and 1b). Common problems facing the developing countries are a shortage of basic resources and capital, the lack of trained manpower, widespread illiteracy, low industrial and agricultural productivity, and uncontrolled population growth. On this matter it should be noted that experts estimate that the global population will be approximately 8.5 billion people in 2025 and that roughly 85 per cent of these people will live in developing countries. Population growth and poor utilisation patterns have reduced the per capita arable rates in most of the developing countries which has, in turn, limited food production in many of these countries.

It is most unfortunate that although more than 75 per cent of the global population resides in developing countries, this group will in the year 2000 have less than 10 per cent of the global access to communication and connectivity, which represents a true measurement

of economic advancement. Even by 2025, it is expected that over 30 per cent of the population in developing countries will still be illiterate.

On the other hand, as the applications of new technical innovations in developed countries multiplies and as science and technology is increasingly used by these countries as a currency of power, the economic, social and cultural gap between the developed and developing countries is getting wider. The lack of capital, technical manpower and adequate industrial bases, in addition to the lack of exposure to deal with complex and unfamiliar technologies, have only served to increase this ever-widening gap. For a developing country with a large land area and a large population, only the purposeful and imaginative adoption of advanced technologies -- such as space -- can initiate a total process of development to leapfrog from a state of backwardness and poverty to advancement and prosperity.

SPACE TECHNOLOGY FOR DEVELOPING COUNTRIES

Over the last three decades it has been clearly demonstrated that space technology and its applications has enormous potential for transforming human lives. The direct benefits from this technology to the vital sectors of the human life cycle, particularly in providing unique solutions for achieving global communication, even for remote areas, for closely monitoring meteorological developments, and for conservation, monitoring and management of natural resources, have already significantly contributed to the development of human society. Most of the developing countries are blessed with abundant natural resources but, unlike in the developed countries, they are not yet optimally exploited. Successful application of space technology for long distance communication, TV and radio broadcasting, long distance education, meteorological observation, disaster warning, agricultural production estimation, forest surveys, mineral prospecting, drought monitoring, environmental studies, etc., by many developing countries including Bangladesh, Brazil, China, India, Indonesia, Malaysia and Pakistan, provides many concrete examples for other developing countries to follow.

SPACE PROGRAMME IMPLEMENTATION

Implementation of a successful space programme requires a strong determination by national policy makers with visionary zeal, as well as mechanisms for effective interaction between the various agencies of the government and social groups, and an appropriate industrial and institutional infrastructure. In order to ensure the necessary public support, the advantages of space technology over other systems must be well demonstrated.

Space programme implementation involves formulating well defined objectives, establishment of a suitable organization, allocation of commensurate financial resources, development of a competent technical manpower base, acquisition of a strong technological capability and establishment of the requisite industrial infrastructure.

Definition of Objectives

While the need for employing space technology for national development is acknowledged, it should be accepted that every country need not develop a complete space programme comprised of its own satellites, launch vehicles and other space and ground systems. For example, countries such as Brazil, China, and India are subcontinental in size and their space technology and application programmes reflect their vast needs and resources. While these countries have been extremely successful utilising this approach, it may be neither feasible nor necessary for most other developing countries (See figure 1).

The objectives of a national space programme must be defined in the context of the existing situation within a country. In particular, factors such as a country's capabilities and readiness to absorb advanced technology, the availability of financial and manpower resources, technical and industrial capabilities and the prioritisation of problems facing the country, must all be considered. While a long-term objective can be to establish a self-sustained, fully operational space-based infrastructure system with a compatible industrial infrastructure and indigenous technological capabilities, the immediate objective should be to demonstrate the potential of space technology for solving the critical problems of the country. Only this will generate the interest and ensure the sustained support of the public and policy makers for a space programme. As a country learns to apply space technology and becomes convinced of its advantages over other conventional systems, the establishment of operational systems and development of the necessary technological base within the country can be attempted.

Organizational Establishment

The success of any high technology organization will ultimately depend on its personnel. A space organization needs highly motivated and dynamic people with an able leader who has both technical and administrative acumen and the vision to foresee the country's requirements. Because of the highly multidisciplinary nature of such an organization, it must be established in such a way so as to ensure effective communication and close interaction between its personnel, and to place a strong emphasis on team work. The organization as well the political leadership in the country, should have the resilience to accept a few setbacks in realising the objectives as they are common in any high technology endeavour. The organization should be able to function with a minimum of bureaucratic interference and the programmes formulated should have the support from the country's top political leadership. The organization should, at the same time, be flexible and able to accept changes as the programme matures and grows from an experimental phase, through the demonstration phases, to a full-fledged operational phase (See figure 2).

A space programme requires strong administrative support so that the time and efforts of scientists and technologists are not frittered away on routine matters such as personnel, procurement and contract management, finance and accounts, infrastructure establishment and maintenance, etc. The organizational structure should be designed so technical expertise in different areas is increased while the organization simultaneously implements operational

space systems. A matrix type of management structure can enable realisation of multiple projects with several work centres and multi-agency involvement. The active participation of academic and research institutions, industries and, most importantly, the end users, is *sine-qua-non* for a successful space programme (See figure 3).

The integration of organizational activities for the fulfillment of the stated objectives through periodical technical reviews can help reduce wasteful expenditure and efforts. Adequate measures for cost and schedule control should also be built into the system. Before deciding on the organization of a space programme, it is essential for the developing countries to study the programmes already established in other countries, especially in the developing countries, and to develop the most appropriate structure to suit their specific needs (See table 2).

Financial Resources

The availability of funds is one of the major constraints that keeps developing countries from organizing and implementing a successful space programme. The significantly high cost of space infrastructure, the long lead times required before benefits are realised, the rapid obsolescence of certain technologies and the low confidence in the efficacy of high technology programmes that often results, trigger adverse reactions from the public and increase pressure on decision makers to withdraw financial support. Hence, before implementation of any space programme a detailed cost-benefit analysis must be conducted for each area of space applications. Over the long-term, such cost-benefit analyses must be conducted for selective technology development and for establishment of industrial production capability within the country.

In the initial stages, efforts should be made to cooperate with other developed and/or developing countries who have the necessary expertise in implementing space programmes, and assistance should be obtained from various international funding agencies. Within the country, while it is necessary to obtain the financial resources from the government to the extent necessary for demonstrating the potential of space technology and to set up a seed organizational infrastructure, the user agencies in the country such as the telecommunication and broadcasting agencies as well as the users of satellite data such as the departments of agriculture, forest, water resources, land use, mines, etc., must provide the funds for further growth and sustenance of the programme so as to generate a sense of participation and to make them accountable for the effective utilisation of the space-based systems.

Financial planning should be based on a long-term strategy and should include a blueprint of activities, planned for in at least 10 year periods, and containing detailed cost estimates for the most immediate programmes. Such a planning process will help avoid spreading the financial resources too thin and will also keep policy makers from losing sight of the organization's long-term objectives. The rapid obsolescence of technology also demands zero-based budgeting techniques involving constant review of the relevance of the projects which are being funded and their method of realisation. Close scrutiny of cost and

schedule overruns, if any are present, along with the progress made, must be a central element of any high technology programme.

Especially in regards to the space segment, developing countries should cooperate with other developing countries with similar requirements. Such mutually beneficial cooperation is the most cost-effective method of implementation, particularly for satellite systems, which, whether being used for communications, resources survey or another purpose, can always serve a large geographical land mass with a properly designed ground segment.

Manpower Development

A national space programme can be sustained only with an assured and continuous availability of technical manpower. This also enables the space programme to become, over time, self-sustaining and able to keep up with technological developments in the rest of the world. Manpower development and training therefore assumes a place of significance for any successful space programme. (See figure 4)

In order to acquire basic technology and to form a nucleus of well-trained personnel, cooperation with space agencies in other countries is essential during the initial phase of a space programme. Once formed, this nucleus should in turn be effectively used to propagate the high technology culture to other scientific/technological personnel. Simultaneously, efforts should be made to develop a scientific temper so that the space programme can be supported and sustained by endogenous personnel and, as a spin-off, improve the general intellectual level in the country. The curricula at the higher secondary and college levels should include space-related subjects so that graduates could be utilised by the country's space programme. Encouragement, including financial and technical assistance, should be provided for conducting fundamental research in existing academic and research institutions which can benefit the space programme.

The existing technical workforce within a country must be able to follow the latest technological developments. This can be accomplished through periodical reorientation courses and through organizational participation in national and international symposia, conferences and workshops, space training courses and exchange arrangements with other countries. the establishment of good technical libraries, sharing of knowledge through technical reports, procurement of journals on space subjects, etc., are essential for sustaining a good space programme.

Technology Development

No country can absorb, adopt and sustain a high technology infrastructure unless a strong technology base is developed within the country. However, it is vital that the technology development programme is carefully planned taking into consideration current capabilities, industrial infrastructure, financial situation and general economic viability. It should be noted that even the developed countries depend on others countries for component

and subsystem procurement for their space programmes. This is because of the high cost of investment, the highly skilled manpower requirements involved and the low quantity of systems generally needed.

Hence technologies which are highly relevant and justify the investment required for producing large quantities must be selected for development. It is worthwhile to develop the ground hardware essential for space application areas which are required in large quantities before embarking on technologies for space hardware and entire space systems. In fact, it is not really essential for every country to launch its own satellite. What is important is to make use of the space technology for operational applications of direct relevance to the country. The technology development programme must therefore involve the research establishments, user agencies and industry to develop the technologies consistent with the country's basic requirements.

Many technologies used in space are also widely required in other areas, especially in electronics, telecommunication, computers, materials, structures, chemical, mechanical fabrication, etc. Therefore, efforts should be made to avoid duplication of developmental efforts and the establishment of redundant, and costly infrastructure and the wasting of valuable technical man power. As far as possible, the development of space technologies should be delegated to agencies who are already engaged in development of related technologies.

In the long run, a properly planned technology development programme should not only lead to a self-sustaining space programme, but should also result in spin-off benefits in the form of a gross qualitative improvement of a country's research and development capabilities as well as its industrial base. This will also result in numerous commercial benefits.

Infrastructure

For sustaining a meaningful space programme, either a space or ground segment, it is essential to develop the requisite research and development and industrial infrastructure. Industrial and research and development facilities should be planned in a phased manner such that the immediate requirements for applying space technology, such as the ground equipment required in the areas of communications, remote sensing and meteorology, are taken up first. Gradually, the capability could be increased towards the goal of developing an indigenous space segment, if this step was determined to be needed. It is essential that the infrastructure built is optimally used and wherever the utilisation is not commensurate with the investment, cooperative ventures with other countries, both developed and developing, should be pursued. As far as possible, the existing industrial capability of a country should be upgraded in order to allow development of space hardware.

Product development efforts should have the full participation of the industry from the very beginning so that the technology for producing the products is immediately available to

industry for production and the necessary research and development manpower and facilities are released for further research and development work.

A strong industrial infrastructure, supported by a competent research and development organization, is absolutely necessary for establishing, and then sustaining, an up-to-date space technology infrastructure.

INTERNATIONAL COOPERATION AND ASSISTANCE

Space technology is new compared to other more conventional technologies. It is therefore difficult, especially for the developing countries, to *ab-initio* establish a space technology infrastructure. It is difficult even to convince the decision makers to adopt such technologies unless the system is thoroughly demonstrated. As has been stressed elsewhere, it is much more important to tap the potential of space technology for operational applications purposes. Hence, it is important for the developing countries to seek assistance from countries that already have successful space programmes for conducting system studies, experiments and demonstrations as well as for developing and establishing operational systems and programmes. It is therefore more effective to cooperate with other developing countries with similar requirements for space-based systems, in developing such systems and making them operational.

A cooperative space programme can be the most cost-effective way, because, as noted above, the space segment can always serve large geographic areas as long as the ground segment is designed with this in mind. Today there are international satellite systems such as INTELSAT and INMARSAT, regional systems such as EUTELSAT, ARABSAT, ASIASAT, etc., and the national systems such as India's INSAT, Indonesia's PALAPA and a number of privately owned systems in the United States. There are also resource survey-oriented space systems such as LANDSAT, SPOT and ERS. Processed data can be obtained directly from the agencies that operate these systems or users may receive data and process it themselves.

The most important constraint, the developing countries face is that of resources, both technical manpower and financial. Greater international assistance has to be organized to tackle this problem to enable the developing countries to initiate concrete space programmes. Developing countries should also be fully encouraged to share their experience with other developing countries in order to find common solutions to their common problems. The forms of international assistance required by the developing countries include:

- strengthening of technical training programmes to enable planners, decision makers and scientists in the developing countries to adopt space technology for solving their national problems. This requires substantial funding from advanced countries with well established space programmes and the convening of training programmes in different parts of the world;

- improved communication and utilisation of space technology for educational purposes. It is only through rapid education, backed up by resources, that increased food productivity, optimal management of land and water resources and adequate health care can be achieved;

- helping developing countries to evolve and implement suitable space-based development strategies such as integrated sustainable development;

- providing data from satellites such as the LANDSAT, SPOT, MOS, ERS and IRS to all countries at affordable prices and establishing receiving stations to fill the existing gaps in coverage;

- recognising that capabilities have to be augmented in the developing countries for them to effectively apply space technology, depending on their specific needs and priorities. It is also important to stimulate the growth of indigenous nuclei to establish self-sustaining space programme in these countries and to avoid their perpetual dependency on the developed countries, if necessary, through technology transfer at concessional prices. What the developing countries need is the fishing rod and not the fish;

- strengthening international organizations such as the UN, FAO, WMO, UNICEF, etc., to enable them to effectively channel the required assistance to developing countries for establishing their own regional and multilateral space programmes.

INDIA'S EXPERIENCE IN ESTABLISHING THE ORGANIZATIONAL AND INSTITUTIONAL INFRASTRUCTURE FOR A NATIONAL SPACE PROGRAMME

In India today, space is a vital element of the country's infrastructure and is used for telecommunications, TV broadcasting, including long distance education, meteorological services, disaster warning and for monitoring and managing natural resources. The Indian space programme was formally organized in 1972, with the establishment of the Space Commission which formulated the policies for the space programme, and the Department of Space/Indian Space Research Organisation which was charged with executing the programme. The programme was initiated with a well defined objective of using space technology for providing services in the areas of communication, meteorology, and resources survey and management.

During the early phase of the Indian space programme attention was focused on establishment of a national technological base through the establishment of a technological infrastructure and capability for indigenous development of rocket and satellite technology and generating the core manpower resources for carrying out these tasks. During the 1970s the efforts of the space programme were primarily geared towards research and development in

a variety of scientific and engineering disciplines of relevance to launch vehicles and satellites. Large scale experiments in baseline areas such as communications and remote sensing were also conducted and the use of satellites built by ISRO and other foreign space agencies was encouraged. In addition to the successful launching of six satellites, during this decade the Indian space programme developed several experimental application satellites for conducting communication and remote sensing experiments and developed a satellite launch vehicle, the SLV-3, capable of launching a 40 kg satellite into near earth orbit.

These experiments and demonstrations led to the evolution of the operational INSAT system for telecommunication, TV broadcasting, radio networking and meteorological applications including disaster warning. While the first generation INSAT series satellites were procured abroad, the more powerful, second generation INSAT series have all been designed and developed within India. Two of these satellites are already operational: INSAT-2A was launched in July 1992 and INSAT-2B was launched in July 1993. Likewise the country has established an endogenously-produced satellite remote sensing system with the launch of two Indian Remote Sensing satellites, IRS-1A launched in March 1988 and IRS-1B launched in August 1991. These satellites have become the mainstay of the national natural resources management system. More advanced satellites in both the INSAT and IRS series are now being built in India.

India has also started development of an indigenous launch capability through the experimental vehicles SLV-3, three of which were launched during the early 1980s and the ASLV launched in May 1992. The development and launch of polar sun synchronous and geosynchronous launch vehicles are the major milestones planned for the 1990's in addition to the initiation of technological development activities for the next generation of INSAT and IRS satellites. The turn of the century could see India achieve complete self-sufficiency in both the areas of satellite and launch vehicle technology.

The Government of India has attached great importance to the space programme and the programme is overseen by the Prime Minister himself who holds the space portfolio (See figure 5). The Space commission, chaired by the Secretary to the Department of Space, formulates the policies which take into consideration the country's overall needs, technical capabilities and financial aspects. The two operational space systems, INSAT and IRS, have full user participation from the time user requirements are formulated and the specifications for the space systems are determined. Users also participate in all reviews as the implementation of the programmes progresses. At the same time they are accountable for the effective use of the space systems once implemented.

The maturity of the space programme in India has enabled it to not only meet the country's requirements for space-based services but also to offer these services to other countries.

Thus, starting with experiments and demonstrations, India has today established a viable, integrated, operational, and self-reliant space programme fully supported, accepted and

adopted by the people. Perhaps, many developing countries can benefit from India's experience in planning and implementing a successful space programme.

CONCLUSION

Science and technology can make significant contributions toward solving the pressing problems in developing countries. Space technology has immense potential for upgrading the living standards of society as a whole. It is the new frontier which must, out of necessity, become man's greatest enterprise for solving national problems in a realistic way. A strong commitment by national policy makers, well-defined objectives, commensurate finance allocation, close interaction between the users and industry and meaningful international cooperation and assistance are essential for developing a space technology infrastructure in developing countries. Because space technology is multidisciplinary in nature, the organizational establishment must ensure effective communication and close interaction between its personnel, and place a strong emphasis on team work. The implementation of the planned programme should start with space application projects which are of immediate relevance to the country's needs and should be followed by commensurate technology and industrial capacity development. Creation of the necessary manpower base is also essential for building and sustaining a space programme while international assistance in various forms is essential for the developing countries to be able to harness the benefits of space technology. India's successful space programme is a worthy example for other developing countries to follow as they try to initiate and sustain a viable, self-supporting space programme to meet the vital development needs of their societies.

Table 1a **Estimated Expenditure and Percentage Share of R&D for 1970, 1975 and 1980 by Continent**

CONTINENT	Expenditure on R&D in US$ billions; % share in brackets		
	1970	1975	1980
AFRICA	0.2 (0.3)	0.5 (0.4)	1.2 (0.6)
AMERICA	28.1 (45.2)	40.1 (35.2)	70.4 (33.9)
ASIA	4.6 (7.4)	12.5 (11.0)	31.2 (15.0)
EUROPE	15.7 (25.3)	36.4 (32.0)	70.7 (34.0)
OCEANIA	0.5 (0.8)	1.2 (1.0)	1.9 (0.9)
USSR	13.0 (20.9)	23.2 (20.4)	32.4 (15.6)

Table-1b: Expenditure on R&D as percentage of GNP

0 - 0.5%		0.6% - 1.0%		1.1% - 2.0%		2.1% - 3.0%		3.1% - 5.0%	
Egypt	0.2 (1982)	Brazil	0.7 (1982)	Australia	1.3 (1985)	FRG	2.5 (1983)	Czechos-lovakia	4.1 (1986)
Indonesia	0.3 (1986)	Cuba	0.6 (1984)	Austria	1.2 (1981)	France	2.3 (1985)	GDR	4.5 (1986)
Nigeria	0.3 (1977)	Yugoslavia	0.8 (1986)	Canada	1.5 (1985)	Hungary	2.6 (1986)	USSR	5.1 (1986)
Pakistan	0.3 (1984)	India	1.0 (1988)	Italy	1.3 (1985)	Japan	2.8 (1985)		
Philippines	0.2 (1982)			Republic of Korea	1.8 (1986)	Sweden	3.0 (1985)		
Venezuela	0.4 (1985)					UK USA	2.2 (1983) 2.8 (1986)		

* Figures in brackets indicate years

[Source : Research & Development Statistics, 1988-89, Department of Science & Technology, Government of India]

Table 2

Table-2 : Basic Organisational Models for Space Missions

Organisational Model	Typical examples
Programmes developed and operated by national space agencies (Type 1)	NASA Tracking and Data Relay Satellite System Indian Space Research Organisation, NASDA Experimental Test Satellite Programme
Programmes developed and operated by a new government agency created for a specific technical mission (Type 2)	National Oceanographic and Atmospheric Administration - US Landsat and weather satellite programmes
Nationally operated systems run by established agencies (Type 3)	TV SAT and Kopernicus (Germany) TDF and Telecom (France)
Programmes operated by regional intergovernmental organisations (Type 4)	NATO Communications Programme Eutelsat
Programmes operated by universal intergovernmental organisations (Type 5)	United Nations Emergency Communications System
Programmes operated by hybrid national/ private organisations (Type 6)	Canadian Telesat satellite system
Hybrid governmental/private international systems (Type 7)	Intelsat, Inmarsat, Eutelsat, Arianespace
Private domestic satellite ventures (Type 8)	Hughes Galaxy System (USA) Restructured Aussat System (Australia)
Privately owned regional or international systems (Type 9)	Asiasat, PanAmSat - Alpha Lyracom, Astra

(Ref: Pelton, Joseph N., 1992, Organising large space activities, Space Policy, August 1992)

Figure 1

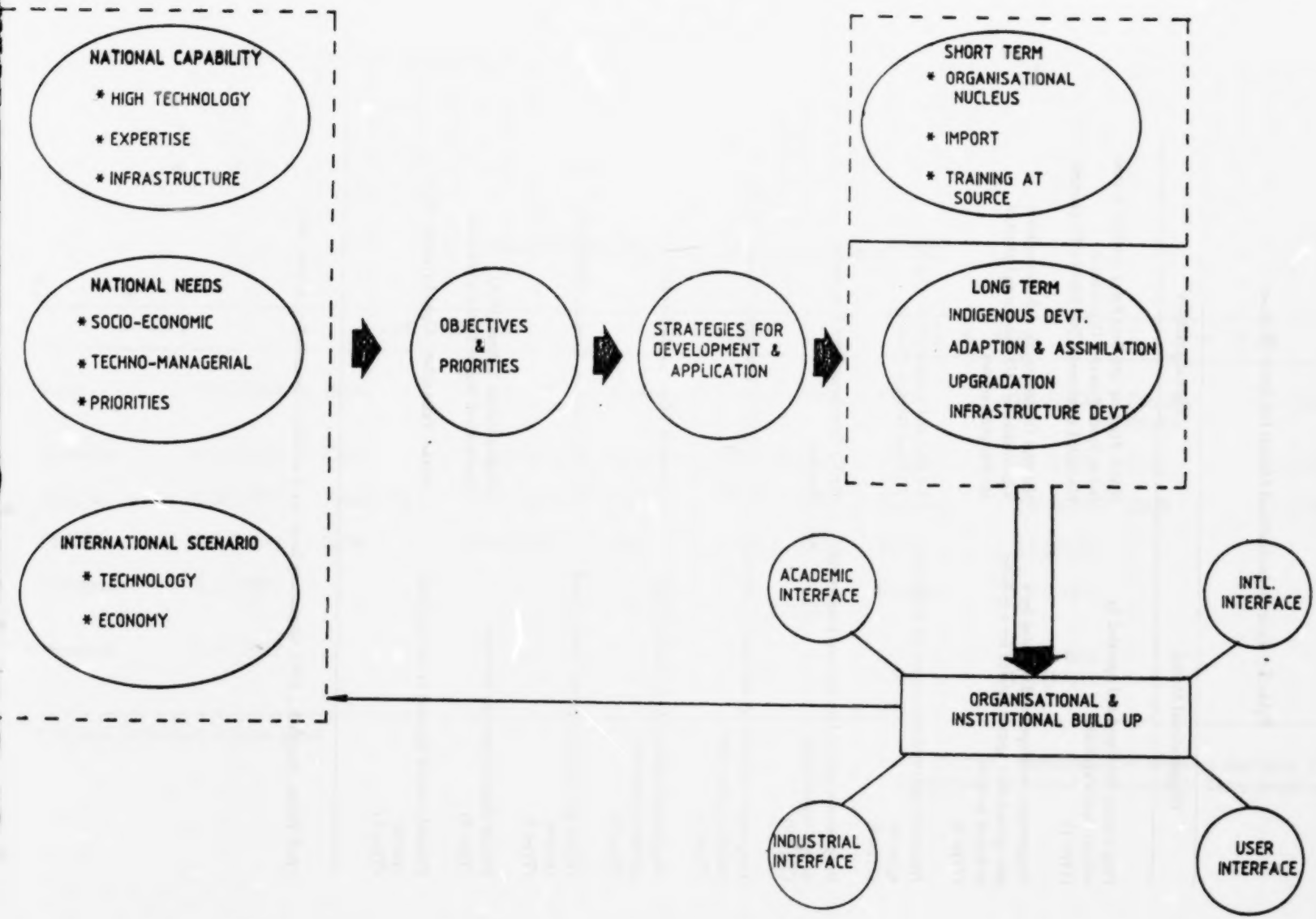

Fig. 1 : Towards a National Space Programme

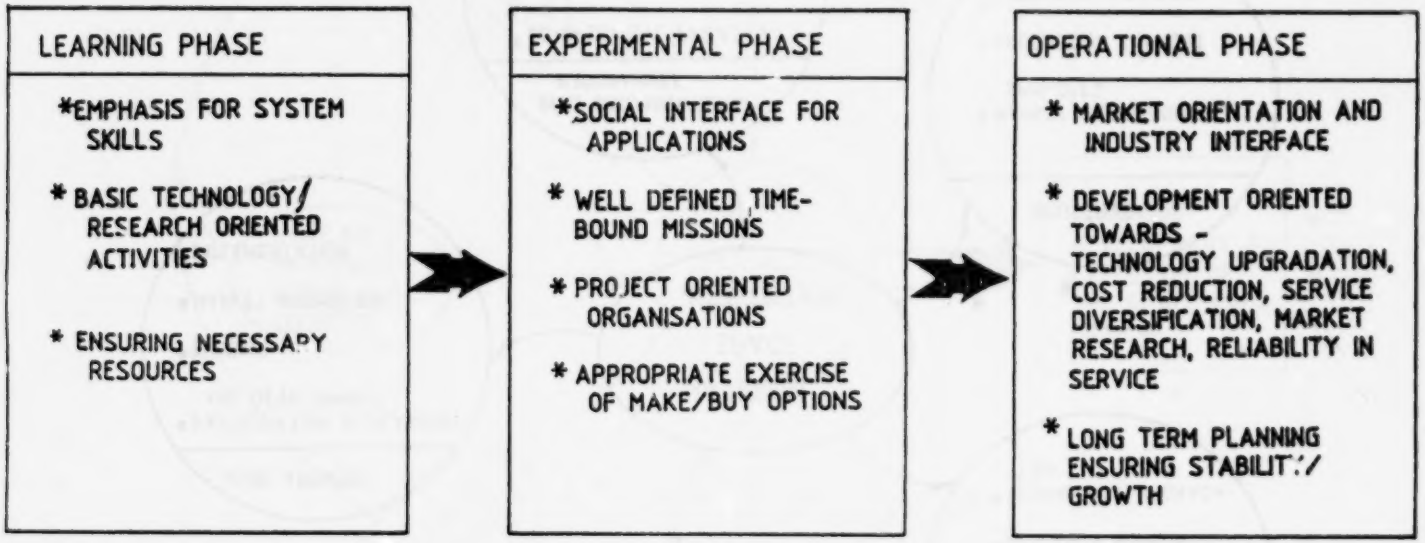
LEARNING PHASE
*EMPHASIS FOR SYSTEM SKILLS
* BASIC TECHNOLOGY/ RESEARCH ORIENTED ACTIVITIES
* ENSURING NECESSARY RESOURCES
EXPERIMENTAL PHASE
*SOCIAL INTERFACE FOR APPLICATIONS
* WELL DEFINED TIME-BOUND MISSIONS
* PROJECT ORIENTED ORGANISATIONS
* APPROPRIATE EXERCISE OF MAKE/BUY OPTIONS
OPERATIONAL PHASE
* MARKET ORIENTATION AND INDUSTRY INTERFACE
* DEVELOPMENT ORIENTED TOWARDS - TECHNOLOGY UPGRADATION, COST REDUCTION, SERVICE DIVERSIFICATION, MARKET RESEARCH, RELIABILITY IN SERVICE
* LONG TERM PLANNING ENSURING STABILITY/ GROWTH

Fig. 2 : Organisational evolution for National Space Programme

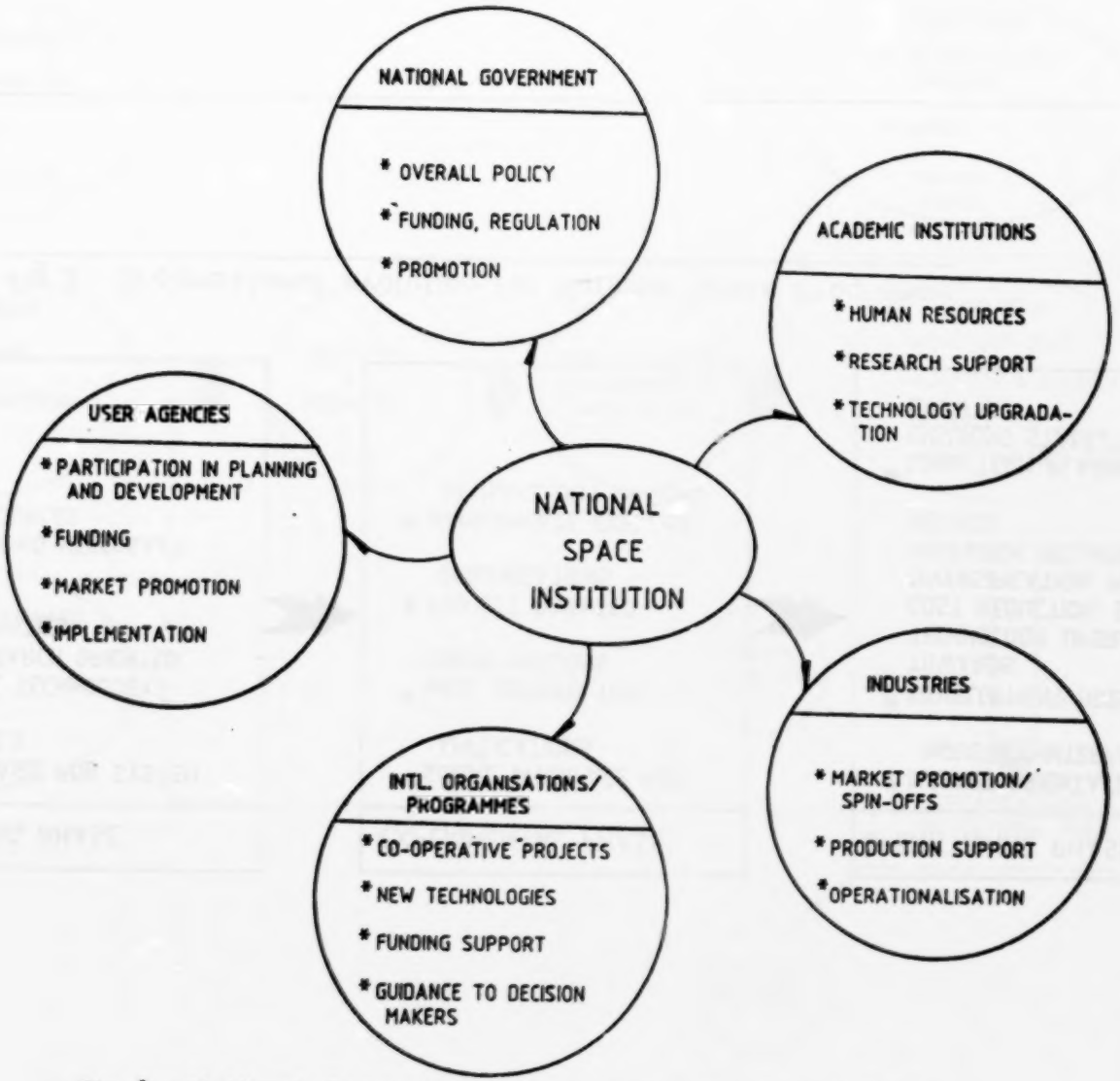

Fig. 3 : National Space Institutions/Infrastructure interfaces

Figure 4

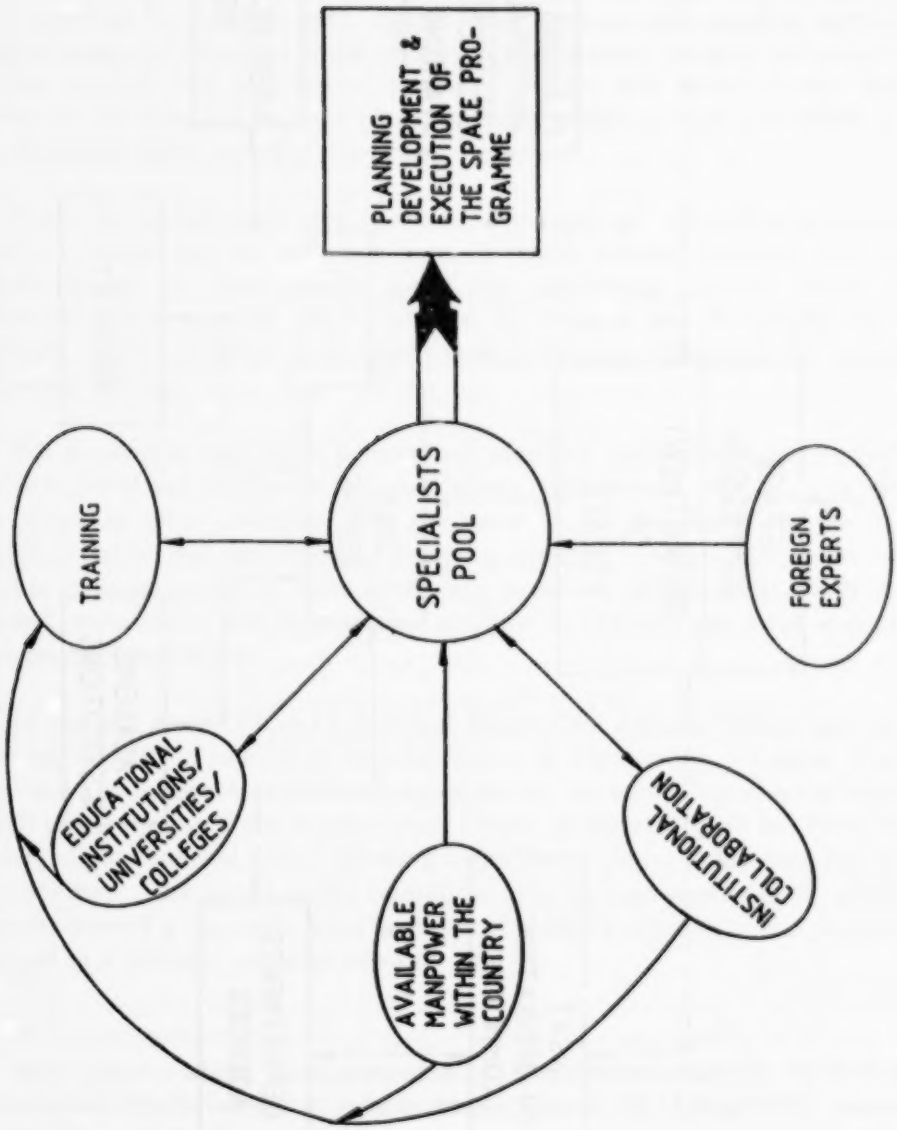

Fig. 4 : Manpower development for a National Space Programme

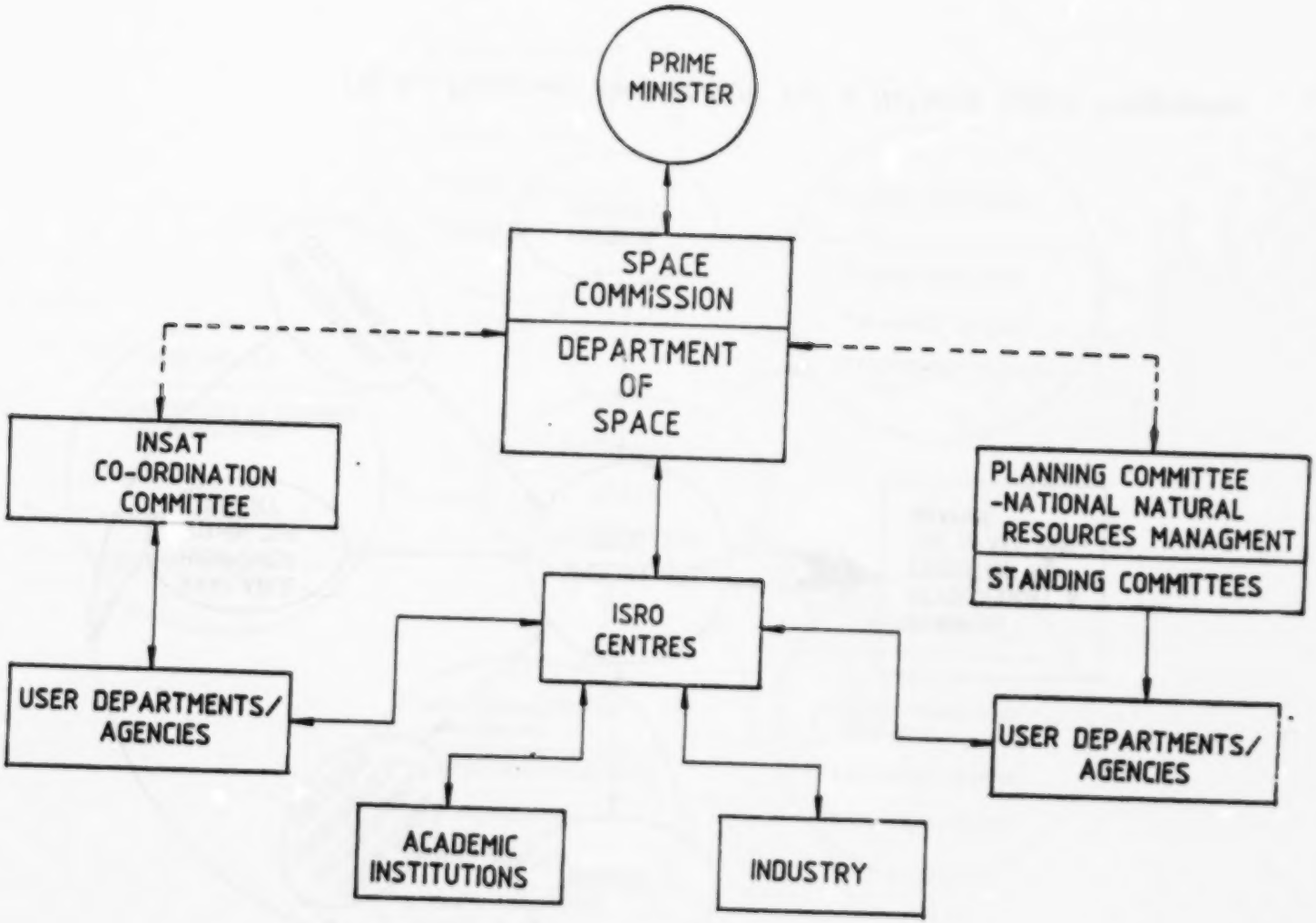

Fig. 5 : ORGANISATIONAL STRUCTURE OF ISRO

SATELLITE COMMUNICATIONS AS A TOOL FOR ECONOMIC AND SOCIAL DEVELOPMENT: THE INTELSAT PERSPECTIVE*

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The power of satellite communications has proven itself over the years to be absolutely essential for economic and social development. The reliable telephone, broadcasting, and data services provided by satellites have created better medical and education services, a healthier business climate, and increased social cohesiveness in countries around the world. Furthermore, a satellite network can be installed relatively quickly and inexpensively, especially when compared to the time and expense of constructing terrestrial networks within a country, and laying submarine cables to other countries.

Given the current pace of geopolitical, economic, and technological change throughout the world, a reliable and cost-effective communications network becomes even more crucial to the achievement of development goals. A developing country must implement a telecommunications network which enables its citizens and businesses to interact with counterparts in other countries on as equal a basis as possible. Otherwise, the country's economic development will lag.

For developing and newly independent countries, satellite systems are therefore a ready answer to regional and worldwide communications requirements. Not only can satellites provide instant access to other countries, they can serve as the foundation for the development of integrated terrestrial and satellite-based domestic networks. Today I will review the applicability of satellite communications to some developing countries, technological trends in space and on the ground, some recent service examples, and how INTELSAT can assist with network design and service implementation.

In my role as INTELSAT's Regional Director for Eastern Europe and the CIS, I know well the applicability of satellite communications from Vladivostok to Prague. That satellites are the only real option for places such as Kazakhstan and the other Central Asian republics is partly the result of the legacy of the former Soviet Union. Network growth has been stunted because previously all international calls originating in the Soviet Union and Eastern Europe were routed through Moscow. The legacy of this centralized network runs counter to the global trend which is the realization of a "geodesic dome" concept of multiple origination and destination points all intertwined in a virtually seamless network.

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* This paper, which was presented at the United Nations Workshop on Space Communications for Development, held in Athens, Greece, 10-12 May 1993, does not necessarily reflect the views of the United Nations.

Geographical barriers and demographical considerations also play a role in determining the efficacy of satellite communications in a particular region. The Central Asian republics are, for the most part, landlocked countries with relatively low population densities. These are the classic characteristics for the type of thin-route links that satellites provide at much lower cost than land lines.

Countries such as Hungary and Poland, however, are a different case. These countries are much more densely populated and terrestrial cellular networks are a good way to bring basic telephone service to many people without having to pay for land line connections to every home. In some cases -- one of which I will describe below -- cellular systems are already interconnecting via satellite to achieve complete domestic coverage. The point in the cases of these regions, and elsewhere in the developing world, is that the provision of basic telephony and even more advanced services need not be overly expensive.

A number of ways exist to ease the cost of construction of satellite networks: joint ventures, development loans, and the establishment of separate facilities that bypass existing, outdated equipment. The bypass option, is in my opinion much less expensive than replacing old physical plant with new infrastructure.

In Russia, for example, many digital overlay networks that support not only local service, but international traffic via the INTELSAT system as well, have already been installed by joint venture companies. These networks were constructed to achieve, in a relatively short time, a more reliable infrastructure separate from the existing public-switched network. This development is making it easier to conduct business there because prior to having immediate access to these international lines, many subsidiary companies in Moscow had to wait for their headquarters overseas to call them.

To give you a couple of examples, Combellga, an alliance of Alcatel, two Russian firms, and Belgacom (INTELSAT's Signatory in Belgium), operates a system in Moscow consisting of 12 PBXs connected by fibre optic link or microwave to a "System 12" switch installed at a nearby INTELSAT Standard B earth station. In Russia's Far East, Cable & Wireless is building a digital overlay network in Nahodka and Sakhalin that will access the INTELSAT satellite at 177°E via a Standard F-1 earth station. Recently, a Japanese carrier announced plans to access this network for its customers in Japan.

In addition to outside investment, various technological trends are combining to make satellite operations even less expensive and, hence, more viable for developing countries. These trends include: lower cost earth stations, compression and digital modulation techniques, and higher-powered and more flexible satellites.

The goal of lowering earth station costs, while increasing service flexibility, has led to phenomenal growth in the VSAT market. Today's VSATs can handle a range of voice, data, and video applications -- everything from satellite news gathering operations used by major broadcasters to low-cost data networks bringing market prices to isolated farmers in rural areas.

Furthermore, many VSATs are transportable which makes service implementation even easier. Even in the United States, which has a low-cost and reliable terrestrial infrastructure, VSAT services have been extremely successful for data applications. Currently, it is estimated that more than 85,000 VSAT terminals operate within the continental United States. Rapid growth of these services is now occurring in Europe and the Asia/Pacific area.

VSAT networks offer features that cannot be provided via terrestrial networks, for example, greater control over operations and costs. The number of parties involved in the communications circuit between any two locations in the network is significantly reduced when the VSAT is located on the customer's premises. The network manager therefore has greater control over the resources of the network and can allocate the resource as needed to meet changing requirements. VSAT technology also provides consistency and flexibility. Every location can have the same equipment, or VSATs can provide protocol conversion to allow devices with different protocols to communicate across the network.

VSAT network costs are also predictable and easier to budget. The shared resource of the satellite, the cost of the hub equipment, the cost of the VSAT, and the cost of maintenance are known, predictable costs. Therefore, the cost of communications at each VSAT is not directly related to the utilization of a particular VSAT. As the network size (i.e., number of VSATs) increases, the cost to provide service at each VSAT decreases.

Another example of a technology that is keeping access costs down is demand assignment multiple access, or DAMA, which is often used in VSAT networks. With DAMA, an operator pays only for capacity in service and not for standby capacity that goes unused during most of the day. This system works even on the level of a single telephone call, as shown by INTELSAT's Australian Signatory, Telstra. Telstra operates the Pacific Area Cooperative Telecommunications (PACT) network which is a completely meshed DAMA service connecting Australia and ten other countries in the area.

Several developing countries use PACT for cost-effective, high-quality, thin route communications for inter-island and international links. Controlled from Sydney, the network provides direct satellite connection on demand, thus sparing users the burden of transit tariffs. The control centre can connect any two stations in the network by assigning a unique pair of frequencies to which they have exclusive use for the duration of their call. A system expansion is in the works and this, along with the coming digitalization of the system, will create even better quality and greater potential for network growth.

The use of small antennas has already brought telephone service to people who may otherwise have had to wait months, if not years, for a terrestrial network to reach them. But INTELSAT can do more and as a result we are working diligently on another type of VSAT, a C-band portable microterminal. The aim of this project is to optimize the design, specify prototype equipment, and demonstrate the use of C-band portable microterminals as small as 50 cm. This concept has applications in thin-route telephony, broadcast or print news gathering operations, two-way data and duplex voice applications and emergency service restoration.

INTELSAT's objective is introduction of a new VSAT service at the end of 1993, after the development, delivery and demonstration of a prototype.

This VSAT initiative, together with cost reduction incentives -- as evidenced by progressive tariff reductions, long-term commitment discounts and various promotional programmes -- demonstrate the Organization's goal of increasing access to the global system at reduced cost.

Other initiatives are being taken at the grassroots level to increase service efficiency. One example is INTELSAT's on-going conversion from an analogue to a completely digital network by the turn of the century. Conversion to an all-digital network will lead to increased system efficiency as the result of a greater number of derived circuits per unit of capacity and greater transmission reliability through error detection and correction techniques. INTELSAT is assisting its users in this conversion, and in many other areas as well, through its Assistance and Development and Signatory Training Programmes (IADP and ISTP). These are two important tools for achieving the goal of creating of a modern telecommunications infrastructure.

In addition, INTELSAT recently announced an innovative programme of financial assistance to our Signatories to speed the implementation of digital circuit multiplication equipment. At its meeting last March, the Board of Governors authorized INTELSAT management to make payment to suppliers on behalf of Signatories for digital equipment purchases associated with its use in the INTELSAT system. Furthermore, INTELSAT will give priority in the assignment of IADP resources to assist users in preparing plans and other procurement requirements for the timely provision of this equipment. This programme was well received at the Board and many Signatories indicated a willingness to participate.

Another relatively low-cost technology, the cellular telephone, is hastening the provision of basic services and is proving extremely popular in a number of developing countries.1/ According to a recent report, about 15 countries, including Bolivia, Hungary, Laos, and Zaire, started cellular systems in 1992 as a less expensive way to provide "plain old telephone service" to more people. In many instances, these cellular systems link remote villages with bigger cities that have traditional wire-based telephone service, either through interlocking cells or via satellite, because an individual cell has an extremely limited reach, as compared to a satellite footprint. This brings me to a novel example which illustrates how satellites and cellular systems can work together to the benefit of cost-conscious telecommunications planners.

As part of its programme to enhance its domestic telecommunications infrastructure, Zaire awarded the joint venture firm Telecel a contract to establish and operate separate cellular systems in the country's six largest cities. Of particular interest, though, is Telecel's plan to tie all of these systems together using three MHz of satellite capacity that Zaire has leased from INTELSAT for domestic use. Using an 11 m hub station in Kinshasa and smaller antennas elsewhere, the network will operate in a star configuration, allowing connections between one station and any other via the hub station and INTELSAT.

Coming improvements in on-board technology will also enhance a satellite's switching capabilities, zone configurations and power. For instance, the INTELSAT VII/VII-A series will replace present satellites with a substantial improvement in terms of coverage, performance and capability.

Each INTELSAT VII satellite will have the capacity for up to 90,000 telephone circuits with the use of digital circuit multiplication equipment (DCME) and three television channels simultaneously, as compared to 12,000 telephone calls and two television channels for a V-series satellite. The VII-A spacecraft will carry up to 112,500 circuits and three television channels.

INTELSAT VII/VII-A satellites are designed to be "user friendly", meaning that the satellites have the capability for many reconfigurations to meet changing user needs. These spacecraft will also provide improved C-band coverage, greater Ku-band coverage areas, and antenna steereability to reach as many urban areas as possible. Given the power, available bandwidth, and flexible coverage areas, VSAT network operators will find these spacecraft of particular use in targeting subscribers and expanding service opportunities. Both C-band and Ku-band users will find these satellites easier to access with simple and small antennas.

Even greater and higher-power C-band capacity will be available with the arrival of two INTELSAT VIII satellites, planned for deployment over the Pacific Ocean in September 1995 and January 1996. The VIII-series satellites are designed to meet the requirements for improved C-band coverage and service of INTELSAT users in the Asia-Pacific region, which includes many republics of the former Soviet Union. Each spacecraft will have 44 transponders -- 38 C-band and six Ku-band. The INTELSAT VIII's C-band package will feature six global beam transponders, 12 hemispheric beam transponders, and 20 zone, or spot beam transponders which can be moved easily between high traffic areas.

These satellites will incorporate six-fold C-band frequency reuse, two-fold frequency re-use of expanded C-band capacity, and the highest C-band power level ever for an INTELSAT satellite. The new spacecraft will provide significantly more C-band capacity for public switched telephony and INTELSAT Business Service, better quality for video services, and will encourage new international VSAT applications.

Such capabilities will promote the development of regional networks, as we see in INTELSAT's work with the ASETA and RASCOM projects. ASETA (comprising the countries of Peru, Ecuador, Chile, Bolivia, and Colombia) and INTELSAT have agreed on a final plan for the implementation of its regional system in 1995, through the use of, initially, 12.5 36-MHz transponders on an INTELSAT satellite located at 329° E.

RASCOM, a cooperative effort involving most of the African countries, and INTELSAT are in the process of devising a plan to consolidate all of the existing domestic use leases held by RASCOM members on many INTELSAT satellites on to one or two INTELSAT spacecraft. Both ASETA and RASCOM are using INTELSAT capacity as a prelude to the deployment and operation of dedicated satellites for their regions. With respect to the former Soviet Union,

Turkey is already providing regional services to the Central Asian republics via an INTELSAT satellite over the Indian Ocean.

Although significant cost savings have been achieved, an enhanced satellite communications system is still quite an investment. However, it can be an investment that pays for itself and generates revenues to pay for system upgrades in the future. For emerging nations, a good first step is the establishment of a satellite link for international service. A number of American, European and Japanese firms have invested in developing countries by constructing earth stations and installing switches there for international service. For example, in 1991, the Armenian government and AT&T co-invested in an INTELSAT Standard A earth station for service from Yerevan to New York City. AT&T's 5ESS gateway switch provides 180 circuits for public-switched traffic via the INTELSAT satellite at 359° E.

AT&T will recoup its investment by splitting the tolls from incoming calls with the Armenian carrier. The establishment of international facilities requires much less investment than the construction of domestic service infrastructure, and has the potential to generate substantial revenue. This revenue can be used in turn to subsidize domestic service.

Elsewhere, Hungary and the Czech Republic are nearing completion of new Standard A earth stations to improve their international connections. And recently, Kazakh and Ukrainian authorities have requested INTELSAT's technical assistance for the implementation of Standard A earth stations in those countries.

The establishment of reliable, modern telecommunications networks are essential for developing economies to establish viable commercial environments. In my recent experience, the prime examples are regions in Siberia and the countries of Kazakhstan and Turkmenistan, all of which possess huge oil and gas reserves. Authorities there must facilitate the exploration of these resources with modern telecommunications because oil and gas companies must transmit vast volumes of data associated with petroleum exploration back and forth between their home offices and field operations for research and analysis.

The main point is that in order to take full advantage of economic potential, developing nations must be plugged into world financial markets, news services and telephone systems to become developed nations. This assessment is confirmed by authorities such as the European Bank for Reconstruction and Development. With regards to Eastern Europe, the Bank has set a priority of improving telecommunications and is seeking to invest in, or make loans to, mobile telephone firms there.

Developing countries have many options available for developing their telecommunications infrastructures including the INTELSAT global network and assistance programmes and local terrestrial networks established by joint ventures. I cannot speak for other service providers, but I assure you that INTELSAT stands ready to meet the needs of developing countries around the world.

For 20 years we have provided a variety of domestic services to many countries. We have unmatched worldwide connectivity, unparalleled technical reliability and a commitment to customer service. We are aggressively securing the capacity we need to meet forecast demand and we are developing new services and easier ways to use them. We want to remain the satellite system of choice and become an even greater force for telecommunications development.

1/ Ian Johnson "Developing Countries' Economic Lifeline: The Cellular Phone," *The Baltimore Sun*, 4 April 1993, pp. 1H and 4H.

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THE ROLE OF EUTELSAT IN THE MEDITERRANEAN BASIN AND EASTERN EUROPE*

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INTRODUCTION

I am very pleased indeed to address this important Workshop on Telecommunications and Development, organized by the United Nations. We are here at the heart of an area, the Mediterranean, which always has been, and remains, an exceptional cross-roads of civilizations, where communications take on a particular importance.

Nowadays, traditional communications by land, sea and air are supplemented, sometimes even replaced, by telecommunications.

But in this last decade of the 20th century, the Mediterranean is also the place where a highly developed North-West, meets a developing South-East.

These differences in development are already a source of tension. It is therefore essential to ensure, in the field of telecommunications as in many others, that the former does not remain the "have" and the latter the "have-not".

It is the role that EUTELSAT can play in promoting a balanced telecommunications development in the Mediterranean Basin and Eastern Europe that I would now like to describe.

EUTELSAT'S POLITICAL DIMENSION

From the outset, EUTELSAT reflected a political will to contribute towards greater European unity through cooperation in the telecommunications field. This objective is clearly stated in the Preamble to the EUTELSAT Convention, where the Organization's founders stress "the importance of telecommunications by satellite for the development of relations between their peoples and their economies, and their desire to strengthen their cooperation in this field".

This wish to cooperate extends beyond the geographical and political borders of Europe as they were in 1977 when EUTELSAT was created. The Organization's satellite system was designed from the start to serve all members of the European Broadcasting Union (EBU), which comprises all countries in North Africa and the Middle East. (Syria is an associate member.)

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* This paper, which was presented at the United Nations Workshop on Space Communications for Development, held at Athens, Greece, 10-12 May 1993, does not necessarily reflect the views of the United Nations.

The international treaties (Convention and Operating Agreement) founding the Organization entered into force on 1 September 1985. They were binding upon 26 Members. The Convention is signed by the Governments of Member States (known as "Parties"). The Operating Agreement brings together the national telecommunications operators (known as "Signatories"), who are the Organization's shareholders. This two-tier structure ensures the separation of regulatory and operational functions.

EUTELSAT's basic principles correspond to its public service obligations, such as equality of treatment, universality and continuity.

Services are provided to all EUTELSAT members on a non-discriminatory basis, irrespective of their investment share or geographic location, and tariffs are identical for the same categories of users.

The Organization must also ensure the continuity of services offered. This implies careful planning both of in-orbit sparing for operational satellites and of their timely replacement at the end of their operational lives.

Furthermore, sharing the costs and risks of implementing and operating a space telecommunications system among several countries serves the general interest and leads to economies of scale. For many countries, developing a purely national telecommunications satellite network would represent an unacceptably high cost.

Such a cooperative approach also makes it possible to optimize the use of two increasingly scarce natural resources: radio-electric frequencies and positions on the geostationary orbit.

EUTELSAT's main purpose is not to maximize profit, like a purely commercial entity, but to generate enough revenues to cover operating costs, reimburse the depreciation of investments made by Signatories and provide the latter with an attractive return on their capital. The Convention also specifies that the Organization "shall operate on a sound economic and financial basis, having regard to accepted commercial principles."

Any European State that is a member of the International Telecommunication Union (ITU) can become a member of EUTELSAT. Use of the Organization's satellite system is not restricted to the Signatories who have invested in the system, but applications for space segment capacity must be forwarded to EUTELSAT by Signatories or, in non-Signatory countries, by a telecommunications entity duly authorized by that country.

The EUTELSAT system was designed from the outset to provide full Euro-Mediterranean coverage, such coverage being improved further on EUTELSAT's second generation of satellites.

In 1990, and in response to political developments in that part of our continent, the Organization decided to modify the fourth and fifth EUTELSAT-II satellites to provide improved coverage of Eastern Europe and of the Russian Federation as far as the Ural Mountains.

These initiatives coincided with a wave of requests for EUTELSAT membership from Central and Eastern European countries. Since January 1990, 13 countries have joined the Organization -- Albania, Armenia, Azerbaijan, Bosnia-Herzegovina, Czech Republic, Croatia, Georgia, Hungary, Lithuania, Poland, Romania, Slovakia and Ukraine. Several others are expected to join in the near future. With almost 40 Member States, EUTELSAT has become one of the international organizations with the widest membership in Europe and consequently has taken on a completely new dimension.

The Organization must now serve vast geographical areas in which the telecommunications infrastructure requires swift and radical improvement. Given the truly vital importance of the basic telephony infrastructure, the part played by telecommunications in national and European development policies, not to mention matters relating to network safety in the event of crises, together implies the involvement of public authorities in order to ensure both the necessary guarantees for such large-scale projects and the long-term planning of telecommunications networks.

EUTELSAT is already providing services to a large number of countries in Central and Eastern Europe, including the Baltic States and the CIS, as well as in North Africa and the Middle East. The Organization is potentially in a position to serve the whole of greater Europe as well as the entire Mediterranean Basin.

I would now like to turn to EUTELSAT's economic dimension by discussing the Organization's space segment and services.

EUTELSAT'S ECONOMIC DIMENSION

EUTELSAT is currently operating a fleet of eight geostationary satellites, four of the first generation (EUTELSAT-I), and four of the second generation (EUTELSAT-II). With 90 operational Ku-band transponders in-orbit, EUTELSAT is the prime provider of telecommunications satellite capacity in the Euro-Mediterranean area. A fifth EUTELSAT-II satellite will be launched in December this year, featuring improved coverage of Eastern Europe.

EUTELSAT offers a complete range of telecommunications services, including telephony, business services, distribution of radio and television programmes and land mobile services. All of these categories of services are of direct relevance to countries covered by the system.

TELEPHONY SERVICES

The EUTELSAT telephony service comprises all services routed via the switched network, namely telex, facsimile and voice communications. It uses Time Division Multiple Access (TDMA) technology.

Since it was opened in 1986, this category of service has witnessed regular growth, and almost 18,000 circuits are now in use, representing 120 traffic relations between 20 countries.

Six transponders are now used for TDMA, but the gradual introduction of Digital Circuit Multiplication Equipment (DCME) will allow the traffic carried by each transponder to be doubled. This means that EUTELSAT can meet traffic growth from Central and Eastern Europe and the Mediterranean area.

With the more powerful EUTELSAT-II satellites now in service, it is possible to use smaller antennas for telephony. The total cost of such an earth station is now approximately ECU3 million (US$2.5 million), and equipment of this type can be delivered in 8 to 12 months.

Romania began using the TDMA system at the end of 1991 and a TDMA earth station is currently being tested for operation in Poland. Croatia also plans to introduce such stations this year and Azerbaijan and Bosnia-Herzegovina are considering implementing TDMA earth stations in the future.

It must also be pointed out that the EUTELSAT TDMA tariffs have remained constant since the service was introduced six years ago. This represents a cost reduction of more than 20 per cent in real terms.

In order to enhance the telephony services offered and meet the full range of demand in this area, EUTELSAT has recently introduced an Intermediate Data Rate service. This service offers 2 and 8 Mbit/s carriers, capable of carrying 150 to 600 telephony channels by making use of Digital Circuit Multiplication equipment earth station dishes from 8m down to 2.4m, depending on the quality and cost requirements.

This service is an optimum solution to quickly and inexpensively establish telephony trunk circuits in areas where the terrestrial infrastructure is poor, or to connect peripheral and distant areas of Europe. This contributes to the rapid integration of the new countries from Eastern Europe and thus to the unification of Europe.

Finally, the fact that EUTELSAT satellites are totally transparent make them particularly well suited to the restoration of submarine cable services.

BUSINESS SERVICES

EUTELSAT began offering its fully digital "Satellite Multiservices System" (SMS) in 1986. Thirteen transponders are currently used to provide SMS services, of which six are carried on the EUTELSAT-II-F4 satellite, which provides enhanced coverage of Eastern Europe.

EUTELSAT is the only space segment provider offering a truly pan-European coverage for business services. Direct connections can thus be established, for instance between companies located in Morocco and Russia or in Egypt and Ukraine.

As a result, EUTELSAT SMS services have experienced significant growth. At the end of last year, over 200 full-time SMS networks were in operation. Typical applications include

As a result, EUTELSAT SMS services have experienced significant growth. At the end of last year, over 200 full-time SMS networks were in operation. Typical applications include computer-to-computer links, remote printing, data collection or distribution, financial data broadcasting, telephony and digital audio distribution, environmental data collection, etc.

SMS is marketed by EUTELSAT's 36 Signatories, as well as via a growing number of specialized, licensed VSAT operators in Europe. The SMS system is now providing a large number of communications links into Central and Eastern Europe.

Although the SMS system is essentially designed to meet the requirements of the business community, its low implementation costs and lightweight ground infrastructure also makes it very suitable for rural communications. By using small fixed or transportable earth stations, rural areas and remote communities can immediately benefit from modern technology. In Eastern Europe, North Africa and the Middle East, the use of SMS can enable such rural areas to leap directly from early 20th century telecommunications systems to those of the next millennium.

LAND MOBILE SERVICES

Since January 1991, EUTELSAT has been offering a pan-European messaging and positioning service for land mobiles. Called "EUTELTRACS", it uses the technology developed by Qualcomm in the United States.

EUTELTRACS is mainly intended for road haulage companies operating large fleets throughout the whole EUTELSAT coverage area. Several West European road transport companies which operate in Central and Eastern Europe are already using EUTELTRACS and have found the system to be of invaluable assistance.

There are now twelve EUTELTRACS service providers offering the service in 11 countries, of which Russia is the most recent. The free circulation of mobile terminals is now permitted in more than 20 European countries, including several in Central and Eastern Europe. EUTELTRACS is the only European land mobile system to provide this essential facility. The positioning function is accurate to within approximately 300 metres.

The simplicity and small size of the terminals enable them to be easily installed on other types of vehicles such as emergency vehicles, vessels operating on inland waterways or in coastal waters, etc. Furthermore, there is nothing to prevent using a EUTELTRACS mobile terminal at a fixed location. The lightweight and rugged equipment can easily be made available to people in remote areas (construction sites, mountain communities, etc.) and provides an instant messaging system connecting such groups to the rest of the world. This type of application is also of specific interest to Eastern Europe, North Africa and the Middle East.

There are currently 35 television programmes and more than 40 radio programmes transmitted via the EUTELSAT network. The coverage offered by the Organization allows those programmes to reach 700 million viewers throughout Europe and the Mediterranean Basin.

Most of this utilization is the subject of full-time lease of satellite capacity. The Organization also offers reservation by subscription and occasional use services. The latter category is used for the coverage of news events such as the 1992 Olympic Games. A number of TV and radio programmes transmitted via the EUTELSAT system are already received in various Central and Eastern European countries. Since late 1992, three Central European television channels (one Hungarian and two Polish) have begun using EUTELSAT.

EUTELSAT has undertaken specific actions to promote the development of satellite TV in Central and Eastern Europe. In early 1992, the Organization decided to provide newcomers to TV transponder leasing in that region with temporary uplink facilities by making a transportable earth stations available to them free of charge. Such facilities will be provided for a period of up to six months, and are expected to be ready for service in early 1993.

The Organization is also assisting in the development of a television project known as "MOSAIKA". Its objective is to assist in broadcasting programmes made in Central and Eastern Europe and to contribute towards a greater cultural, economic and political integration of countries in Eastern and Western Europe.

In addition, EUTELSAT is providing capacity for nine channels from Turkey and North Africa (six Turkish programmes, one Tunisian, one Egyptian and one Moroccan). Four transponders on the EUTELSAT II-F4 satellite are also used permanently by the European Broadcasting Union (EBU). The merger between the EBU and its counterpart in Central and Eastern Europe, the "Organization International de Radio et de Television" (AERATE), which became effective last year, has resulted in a single pan-European broadcasting and exchange network. With the improved coverage of Eastern Europe offered by EUTELSAT-II- F4, the expanded EBU is now able to reach its member broadcasters in 47 countries with a single satellite.

LOOKING TO THE FUTURE

EUTELSAT is reacting dynamically to the new trends in the telecommunication sector, and is preparing for the future in a number of areas.

One such area is the European satellite television market, which has now become highly competitive. In order to further strengthen its programming offer and to substantially increase its share of the direct-to-home market, EUTELSAT developed the "Hot-Bird" system. This consists of modifying the sixth EUTELSAT-II satellite in order to operate it in the so-called "expansion bands". EUTELSAT-II-F6 will then be co-located with EUTELSAT-II-F1 at 13° E, thereby doubling the number of transponders for entertainment television from this orbital slot.

This satellite will be launched in the fourth quarter of 1994 and will provide complete coverage of Europe, from Portugal to Russia, as well as North Africa and the Middle East.

The Organization is also studying new telephony services, all of which are of direct interest to Eastern Europe and the Mediterranean Basin. Two applications, one being a light telephony system currently being tested in several Central and Eastern European countries, and the other a "suitcase telephone" that could be used in remote and unaccessible areas.

Finally, EUTELSAT has begun active work on its next generation of satellites (EUTELSAT-III), which will be introduced around 1998.

CONCLUSION

In this paper I have tried to explain what EUTELSAT can offer to both Europe and the Mediterranean Basin. The Organization is an exceptional tool for cooperation, built by Europeans for Europeans and their neighbors. Its philosophy is to provide the advantages of modern satellite telecommunications to all its members and users without exception, and hence to promote the economic development and well-being of citizens throughout the entire Euro-Mediterranean area.

As a regional Organization now bringing East, West and South together, EUTELSAT has to serve not only one group of comparatively affluent countries, but the whole of Europe and the Mediterranean Basin with vast differences in social, economic and political development, not to mention telecommunications infrastructure.

The importance of this mission must therefore be carefully balanced against the advantages of telecommunications deregulation. EUTELSAT is open to a progressive evolution in this field but the effect of the measures currently being implemented will require in-depth analysis before any drastic changes can be envisaged.

SATELLITE COMMUNICATIONS SERVICE FOR THE TIBET AUTONOMOUS REGION BY DOMESTIC SATELLITE IN CHINA*

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INTRODUCTION

This article describes the factors to be considered, the type of principles used in the selections process and the refinement of the prototype system that was used in construction of a thin-route satellite telecommunication network in Tibet.

Western China is the country's cradle of culture and economic development. It's territory is vast and it has abundant resources. Applications of satellite communications technology is comparable to early applications in the western countries, and the system is being perfected and continuously expanded. In order to solve the problems of county-to-county telephone communication in Tibet, the government this year began to build a thin-route voice VSAT network, also called voicesat, which consists of 58 terminal stations in Tibet. Before long, this voicesat network will be extended into the territory of Xinjiang, Inner Mongolia, Sichuan and Qinghai provinces and it will connect the important cities and counties located in an area of several million square kilometres. A satellite communication system is the only way to achieve this.

THE SPECIAL GEOGRAPHICAL CONDITIONS IN THE TIBET AUTONOMOUS REGION

Tibet Autonomous Region is part of the Qingzang Highland and the average elevation is about 4000 m above sea level. It has been called "The Roof of the World". On the southern boundary of Tibet is the famous Mt. Qomolangma, which is more than 8800 m above sea level; on the southwestern boundary is Mt. Gangdisi; the northern boundary is formed by the Northern Tibetan Highlands, which lays between Mt. Kunlun and Mt. Tanggula. The total area of the region is 1.2 million km^2; the population is 2.2 million and the average population density is 1.8 people per km^2. There are six prefectures, encompassing 74 counties within the Autonomous Region. The distance between a county and the prefecture centre is generally several hundred km but some are even 1,000 km apart.

Annual rainfall in Tibet is very low and in most parts of the region the annual level is less than 200 mm. There is much sunshine, however, about 3,000 hours annually and this allows the effective use of solar energy. There is little variance in the temperatures among counties: the lowest temperature can reach -20°C and the maximum wind speed can reach about 30 m per

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* This paper, which was presented at the United Nations Workshop on Space Communication for Development, held in Seoul, Republic of Korea, 24-27 November 1992, does not necessarily reflect the views of the United Nations.

second. The electrical supply varies greatly from county to county with some having no electricity at all.

The telephone traffic in Tibet is not heavy due to the sparse population of the region. According to statistics from Lhasa City and the six prefecture centres, we have the following list:

Traffic Area	Calls	Modified Calls	Traffic (Erl)	Predicted Traffic/1998 (Erl)	Predicted Circuits 1998
Lhasa	19881	21869	10.74	43.88	64
Xigaze	3408	3749	1.84	7.52	18
Nagqu	1335	1469	0.72	2.94	10
Sanan	2784	3062	1.50	6.13	16
Qamdo	709	780	0.38	1.55	8
Ali	687	756	0.37	1.51	8
Nyingchi	1966	2163	1.06	4.33	14

There is even less traffic at the county level. Among the 74 counties of Tibet, there are about 51 in which telephone service is inadequate or not available. The scale of the voice VSAT network to be constructed is:

Lhasa City: **1**
Prefecture Centres: **6**
County Centres: **51**

Altogether there will be 58 voice VSAT terminal stations.

The decision was made to select voice VSAT as the primary means of communication in Tibet because the region's vast territory, sparse population and low level of traffic would make traditional wire telecommunications cost ineffective. In order to solve problems in county-to-county telephone communications, China must therefore rely on wireless communications. Among potential wireless communications systems, microwave relay systems are not suitable for thin-route communications. Other wireless communication approaches are: shortwave, UHF and satellite communication.

Shortwave communication is suitable for point-to-point communication at distances from several hundred km to 2,000 km. It is a low cost and effective method but because carrier transmission is not stable, it is not suitable for all-weather operations which requires constant

frequency changes. Additionally, in order to establish a shortwave circuit which meets the requirements of connecting a telephone network, the shortwave transmitting and receiving stations must be constructed separately, thereby increasing construction and maintenance costs. Shortwave systems can therefore only be used in counties where traffic is very light and contact is not frequent.

UHF communication systems are best suited for use in areas with low traffic. Under ideal conditions of no obstructions, and using no relay systems. the maximum communication distance is 40-50 km. Relays are needed for longer distances. In the Tibet Autonomous Region open-wire systems are used in counties that are roughly 100 km from the prefecture centre they belong to. All of the 51 counties in which long-distance communication systems are not established are more than 100 km away from the prefecture centre they belong to. The farthest one is 900 km away from the centre. If UHF communication systems are to be established in these counties, relays must be used, but due to weather conditions and the geographical characteristics of Tibet, it is difficult to establish relay systems.

The first application of satellite communications in Tibet occurred in 1986 when a station with a 12 m antenna was established in Lhasa and direct long distance circuits between Beijing and Lhasa were opened. CVSD/SCPC mode was used initially but because it is only suitable for thin-route communications, it cannot meet the requirement for inter-province communication services. The capacity of the system was expanded to 24 routes in 1988 through the use of FM/FDMA mode. Capacity was expanded a second time in 1990 and through the use satellite circuits an automatic long distance exchange system was established. At the same time, seven earth stations with 6 m antennas and all using CVSD/SCPC mode were established. The establishment of these stations touched off the development of long-distance communication from Lhasa to inland cities. But problems such as the high initial investment, uneven power supplies and high maintenance costs became evident. These problems have prevented the establishment of CVSD/SCPC stations in all the counties in the Tibet Autonomous Region.

Voice VSAT systems which have been developed recently, are a type of small aperture antenna earth-station which operates in C-band and has an antenna aperture of 3-4 m. The advantages of this type of system are: its small size, low power consumption, ease of installation, and low-level of required maintenance. These advantages make it very suitable for used in Tibet.

THE TYPE OF VOICESAT SELECTED AND REFINEMENT OF HARDWARE AND SOFTWARE REQUIREMENTS

After analysis of traffic and the particular environmental conditions in Tibet, it was determined that the most suitable voicesat system for Tibet is SCPC/DAMA. Its advantages are: simple configuration, low-cost, suitable for multiple access, high system capacity, can be easily expanded, and can use an active voice carrier to save satellite power. The DAMA can also greatly increase the utilization ratio of space channels.

Of the several types of VSAT systems based on SCPC/DAMA, the TES system developed by Hughes Network System Co. was selected to be the prototype system to be installed in Tibet. This system was chosen because of its physical and technical properties such as weight, size, power consumption and ease of maintenance all met the particular requirements of Tibet. But some hardware and software refinements were necessary so that the system could run in Tibet and be networked with PSTN.

In order to overcome the problem of uneven power supplies in Tibet, the power of the TES remote station was changed from 220 V AC to 48 V DC. The system can now utilize solar energy when available. The investigation of power supplies in 51 counties shows that there are year-round power supplies in 20 counties but power outages lasting a few days or a few weeks may occur due to natural disasters. The power supply is therefore considered to be in the third category (see figure on page 54). In the other 31 counties power is supplied seasonally meaning power is supplied in summer and stopped in winter. These 31 counties should be considered as having no power supply.

In the six prefectures, four of them can be considered to have second category power supplies and the other two have no power. The power supply scheme is shown in the figure on page 53.

In order for TES to be installed for Tibet to enter the public telephone network of China, the software of the TES must be improved. As part of this effort a programme compatible with the China No.1 Signalling system will be added and a numbering plan identical with the terrestrial network will be used.

The public network signalling system in China (the China No.1 Signalling system) has two kinds of line signals and a register signal. The characteristics of the China No.1 signalling system are: 1) the system is suitable for line exchange and can meet the requirements of automatic and half automatic exchanges; 2) the line signal is recognized and rectified link by link; and 3) the register signal is transmitted in and end-to-end-manner.

DETAILS OF THE SIGNALLING SYSTEM USED IN TIBET:

Type of signalling

a) SPC interworking with VAST: line signalling is 2600 Hz, single frequency (SF); Register signalling is multiple frequency compelled signalling (MFC); and

b) MBD interworking with VSAT: 2-wire loop handset signalling is used. The digits are sent by DC pulses. When a VSAT calls the MBD, the ring current is sent to the MBD and the ring back tone is sent back.

Signalling system specifications

The China No.1 signalling system is similar to CCITT R1 on line signalling and CCITT R2 on register signalling.

Signalling type and sequence of telephone system based on VSAT

The 2600 Hz SF line signalling and MFC register signalling are used when VSAT interworks with SPC toll exchanges. The En-Bloc method is adopted. That is the VSAT sends digits after all digits are received from the outgoing exchange. Digits sent from exchanges are received by the VSAT incoming trunk with MFC method. Then the digits are transferred to the destination VSAT in data communication method. The VSAT outgoing trunk sends the digits to destination exchanges in MFC method. A special handling method is adopted to determine the exact digit length, due to various digit length of area code plus subscriber numbers in China.

After the satellite telephony system is equipped with the China No.1 signalling system, the satellite circuits can be established between every remote VSAT, that is within counties and, prefectures, and between every county and every prefecture centres, every county and Lhasa, and between every prefecture centre and Lhasa. The prefecture centres, county centres and Lhasa centre will be hooked into the national PSTN through the Chengdu VSAT-based gateway station.

The biggest changes in the telecommunication environment in Tibet will take place once the voicesat system is established. The switching equipment will be upgraded while the construction of the voicesat system is underway. The local 200-line automatic exchange will be installed and connected to remote VSATs through MBD in the counties. The toll, combined with 1,240 local exchanges will be installed and connected to VSATs in six prefecture centres and in Lhasa. This digital switching equipment will comprise the automatic switching network between these cities. The 6 m and 12 m earth stations established previously are still used. After the gateway station in Chengdu is installed, either a 12 m station or VSAT system can be used for national or international toll connection originating from Lhasa.

The VSAT system will be used for connections between every county, prefecture, and Lhasa as well as between Tibet and other areas in China and for international toll connections. The 6 m CVSD/SCPC stations, which utilize manual connection methods, will continue to be used for connections between prefecture centres and Lhasa. Telephone service between every county in Tibet will be provided within two years.

THE TRUNK TYPE AND CALL CONNECTION METHOD IN COUNTIES OF TIBET

The local automatic switching equipment installed in every county is connected to the VSAT system through a toll MBD. Two-wire loop handset signalling is used between the MBD and VSAT.

Calls are connected through the following method: When subscribers in any county want to make a toll call, they "113" for MBD registration, then the connection will be made by operators by dialling the called party's number. When the called party is an automatic subscriber, the operator can dial the called party directly. If the called party is a manual subscriber located in Tibet, the operator will dial the called party operator or the operator above the called party, and the connection will be completed by the called party operator. If the called party is a manual subscriber outside Tibet, the operator will dial the MBD in Lhasa through the VSAT system, then the manual toll connection will be completed by the transfer operator through the existing earth station (the 12 m station in Lhasa).

THE TRUNK TYPE AND CALL CONNECTION METHOD IN PREFECTURE CENTRES

The toll and local exchange (S-1240) are going to be installed in every prefecture centre. The interface between these exchange and the VSAT system will be an analog toll trunk. Because the S-1240 does not have an analog trunk, a signalling adaptor - the PCM equipment - - is needed for connections to the VSAT.

Calls within Tibet will be connected by the following method: the connection between every county and every prefecture centre, and between prefecture centres will be done through the VSAT system. If there are no VSATs in the called county, the connection can be put through by the operator of a prefecture centre above the called party and the connection will then be transferred by the operator. Automatic toll service between prefecture centres and Lhasa is provided via the VSAT system. For manual toll service, the subscribers in a prefecture centre or in Lhasa should register the call through the local toll MBD. The operator can then put the call through to the called party through the existing earth stations. The connection is completed by the called party operator. These connections can also be made through the VSAT system.

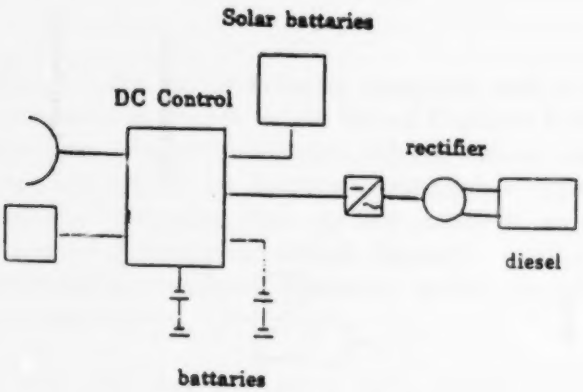
Calls between Tibet and other countries will be connected by the following method: A DDD call from prefecture centres to a national PSTN or an IDD call can be routed via the VSAT system through the gateway station SPC in Chengdu. The connections are then completed by terrestrial circuits. Between prefecture centres and other areas which have manually operated systems, the connection of an incoming call is accomplished by the calling party operator through the national automatic PSTN to prefecture centres. The calling party subscriber will dial "113" for the local toll MBD for registration. The connection of an outgoing call can be made by operator of the prefecture centre. The operator would first dial the operator in Lhasa who would then complete the connection through the existing earth station into the national PSTN.

THE TRUNK TYPE AND CALL CONNECTION METHOD IN LHASA

The trunk type is as that of the prefecture centres. Calls will be connected through the following method: Manual connections between Lhasa and all counties is completed via Tibet's VSAT system. Manual connections between Lhasa and every prefecture centre is completed by the 12 m earth station's or though carry wave circuits. Calls to other areas in China and

international toll calls are carried by the 12 m stations. The VSAT system can be used as a second or backup route.

POWER SUPPLY SYSTEMS



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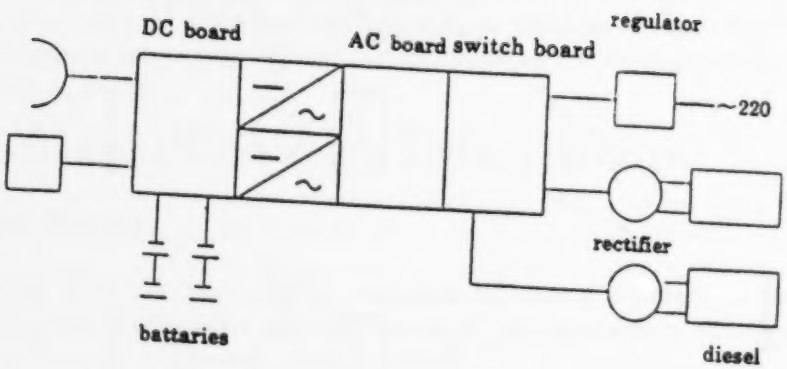
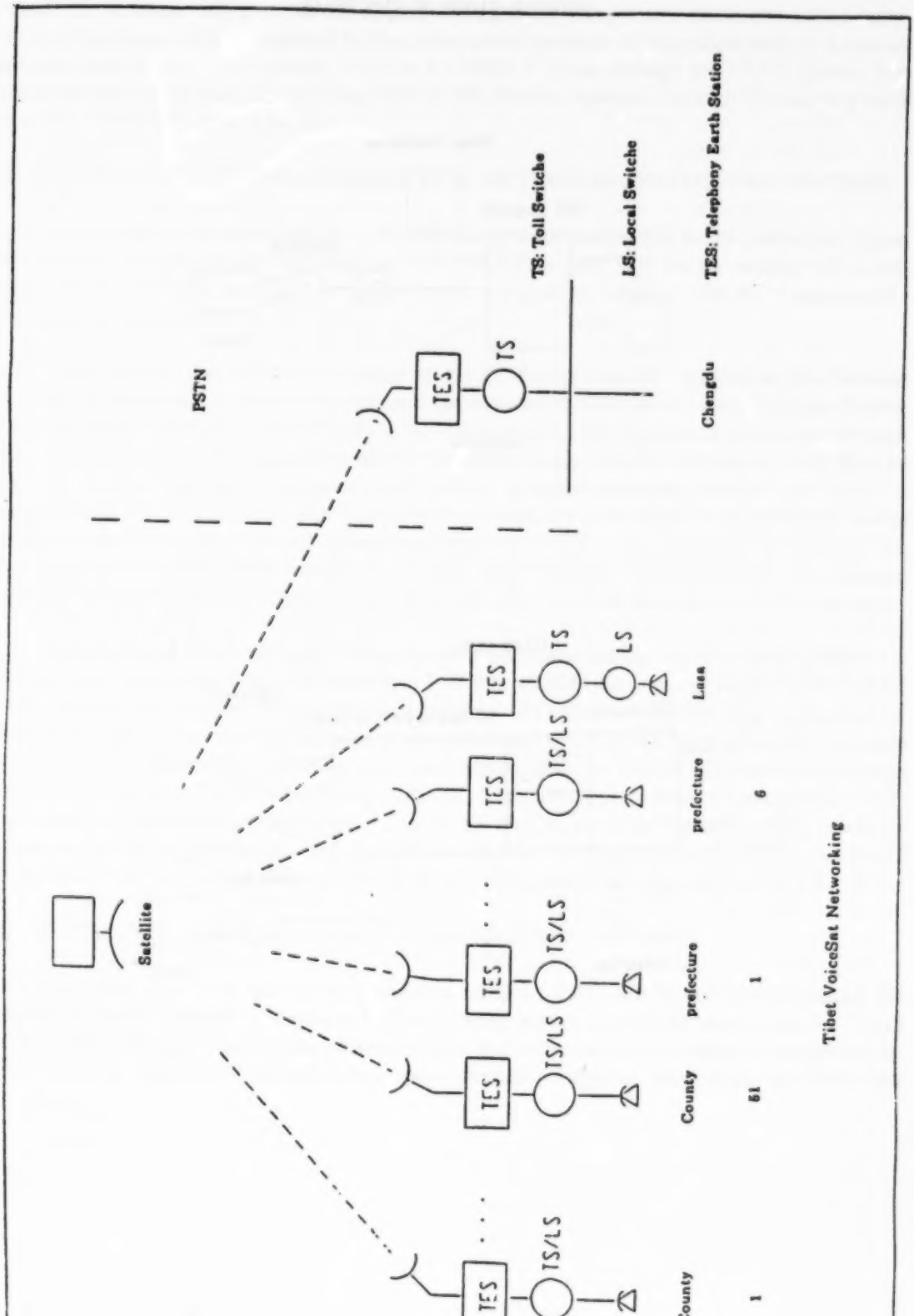


TIBET VOICESAT NETWORKING



THE USE OF INMARSAT IN DISASTER RELIEF AND EMERGENCY ASSISTANCE OPERATIONS*

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INTRODUCTION

This paper describes the use of Inmarsat equipment and services in combatting natural disasters. The International Decade for the Natural Disasters Reduction (IDNDR) has given a strong impetus to disaster mitigation efforts, which include provision of communications to areas not affected by disasters. Although telecommunications cannot prevent a natural disaster from happening, they can help reduce its impact. Inmarsat can be used in all critical phases of dealing with natural disasters: monitoring and prediction, warnings and early intervention measures, emergency operations, and rehabilitation and reconstruction.

Inmarsat has been providing emergency communications since the start of its operations in 1982. Now it is almost taken for granted that the first relief workers to arrive in the area affected by the disaster will carry with them a portable Inmarsat satellite communications terminal.

National and international relief organisations, for example the UNDHA, UNICEF, organizations of the Red Cross/Red Crescent movement, medical and humanitarian relief agencies (e.g. OXFAM, CARE, Medecins sans Frontieres) as well as international aid and development agencies (e.g. UNDP, USAID), own or lease Inmarsat transportable satellite terminals. With the cost of owning and operating an Inmarsat terminal decreasing, more and more organizations are joining the ranks of Inmarsat users, including national emergency and civil defence agencies.

THE USE OF MOBILE SATELLITES IN NATURAL DISASTERS

Contingency Planning

Each year, the world suffers hundreds of natural disasters. Floods, hurricanes, volcanic eruptions, earthquakes and tidal waves of various intensity and physical and social

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* This paper, which was presented at the United Nations/European Space Agency Workshop on Applications of Space Technology to Combat Natural Disasters, held at Mexico City, Mexico, 27 to 30 September 1993, does not necessarily reflect the views of the United Nations.

consequences are reported almost daily. Although certain regions, such as the Caribbean, the southeastern United States, the Bay of Bengal and Southeast Asia, suffer natural disasters most frequently, they can occur virtually anywhere. There is evidence that the frequency and severity of disasters may be increasing.

Suitable contingency plans can help minimize the impact of natural disasters. These plans would typically include the pre-positioning of emergency supplies and communications equipment at strategic locations in areas known to be at risk. As the process of needs identification, funding and deployment can take many months, pre-positioning activity should be started as soon as possible. In addition to contingency plans, it is essential that designated local personnel undertake training and regular reviews to ensure they are ready to operate mobile satellite communications systems when a real disaster occurs.

Another requirement for good contingency planning is the simplification and streamlining of reporting from the field, so that all relevant information can be rapidly and accurately transmitted. One way is to use standardized forms, which can also be computerized. Using this approach, even long lists and reports can be compiled quickly and transmitted via mobile satcoms to disaster relief coordinators and other relevant agencies. For more complex needs, software programs already exist (e.g. the SUMA program developed for PAHO/WHO) for supply and personnel management from the home base.

The agencies typically involved in planning disaster communications are national civil defense and preparedness organizations. The Red Cross and other medically-oriented organizations also participate. Many activities are conducted on a regional basis. For example, virtually every country in Central and South America and the Caribbean has expressed interest in mobile satcoms and although the level of technical ability and technological competence is steadily increasing in these regions, the main stumbling block continues to be a lack of funds for the necessary equipment. The Caribbean Disaster Emergency Response Agency (CDERA), which coordinates the disaster emergency activities of 14 islands, has established a pilot project using Inmarsat terminals as part of their plan to increase emergency preparedness.

Monitoring, Prediction and Early Warning

Inmarsat terminals, coupled with the appropriate sensors, can perform supervisory control and data acquisition functions. Such equipment can play a vital role in providing or improving the monitoring and early warning functions, even from the most remote areas. The monitoring of geothermal and volcanic variables, tectonic plate movement and pressure ridges helps identify potential volcanic or earthquake activity. Mexico has already implemented a line of seismic sensors along the most vulnerable part of its western coast. This system presently uses RF links but these will eventually be replaced by satellite links because they are less susceptible to the effects of natural disasters.

Emergency Operations

When a disaster strikes, telecommunications are often disrupted or rendered ineffective. It could be many hours before the world is even aware of a disaster. Frequently, there is a considerable delay between the onset of the disaster and the arrival of the first relief workers and this in turn leads to valuable time being lost.

Good contingency planning, preparation and access to mobile satcoms enables local authorities to immediately communicate with relief teams and the outside world. This allows the experts to make an initial assessment of the damage, report the facts -- sometimes through the transmission of photos and/or video -- and request appropriate aid in the critical first 48-72 hours when there is the greatest possibility for saving lives

In the absence of locally available Inmarsat equipment, the stricken area must rely on outside sources of telecommunications equipment. Some of the most notable uses of Inmarsat systems by international rescue teams were in the aftermath of the earthquakes in Turkey (1992), Iran (1990) and Armenia (1988), as well as during the volcanic eruption in the Philippines in 1991. Inmarsat was extensively used in the aftermath of hurricane Hugo which devastated the island of Montserrat (1989) and knocked out all of the island's communications links, including fixed satellite and cable links. Inmarsat communications were also utilized after the typhoons and floods in Bangladesh and China (1991), the cyclone Val in Western Samoa and the Indian earthquake and floods in September 1993.

Immediately following a disaster, it is easy for field workers in their vehicles or trucks carrying relief supplies to become immobilized due to local conditions. Therefore, regular communications and position reporting is highly desirable. Using Inmarsat mobile satcoms and global positioning system (GPS) equipment, the operations control is able to monitor the progress and location of all equipped vehicles, as well as send messages to them, regardless of the state of the local infrastructure, weather conditions and other impediments.

Rehabilitation and Reconstruction

Although telecommunications are high on the list of priorities during the rehabilitation and reconstruction phase following a disaster, it could be weeks or even months before the communications infrastructure is back to normal. During this period, mobile and transportable satcoms support rehabilitation work, enabling local government and business to function. They can also be made available for social calling and contacts with the press and other media.

Coordination of relief and rehabilitation work is often difficult and expensive, particularly in massive or complex emergencies. However, recent developments in cellular radio technology and the declining costs of cell site management equipment have resulted in some novel applications. For example, a multi-channel satphone can be connected to a cellular radio microcell, or with a private branch exchange (PBX) to multiple fixed users. A number of manufacturers now offer the requisite equipment for the connections to Inmarsat

satcoms. The average cost per minute in a multichannel operation can be below $3.00 per minute.

Long-term Relief and Development

Many natural disasters have a long term impact on the region where they occur. They can cause severe hardship and dislocation of people whose basic needs remain after the disaster has vanished from the news headlines. The management of supplies from the outside world and possible subsequent re-development work is frequently aided by satcoms, such as those used by United Nations agencies such as UNDP and UNICEF, or private or government relief organizations, such as the Save the Children Fund.

ABOUT INMARSAT

The Inmarsat Organization

Inmarsat is an internationally-owned cooperative. As of October 1993, it had 72 member countries who own shares in Inmarsat via their Signatories. The organization was established in 1979 and is the only global provider of mobile satellite communications for distress, safety and commercial applications at sea, in the air and on land.

Inmarsat is comprised of three bodies: the Assembly of Parties is the highest organ; the Council, which consists of 22 representative Signatories, and serves the same functions as a corporate board of directors; and the Directorate. The Inmarsat Directorate is based in London, and has 600 employees from 50 nations.

Inmarsat Signatories, typically major telecommunications companies, maintain additional staff in their own countries. Most customer enquiries are handled by them or by appropriate service providers and service integrators. Other important entities essential to the functioning of Inmarsat are the Routing Organizations (one per country), which handles satellite terminal commissioning applications, and the Accounting Authorities, which, together with the land earth station (LES) operators, attend to billing and accounting matters.

Communications via Inmarsat

Through its Signatories, Inmarsat offers several different mobile communications systems, interconnected with the public switched networks. Public services provided through the Inmarsat system conform to agreed international standards. They enable the mobile user to roam and operate throughout the world, subject only to national licensing requirements where applicable. This is an important benefit for the disaster relief user as the same equipment can be used all over the world.

Operating through a variety of type-approved terminals -- mobile earth stations (MESs) -- Inmarsat provides a full range of telecommunications services including direct-dial international telephone, telex, facsimile, electronic mail, data communications, as well as

56/64 kbit/s high speed data service. Connections can be made into the public networks, or between two or more Inmarsat mobile terminals.

Most countries allow importation of mobile terminals for disaster relief without any limitations, or only with a minimum of licensing/regulatory requirements. Inmarsat is working closely with the international regulatory bodies and regional telecommunications organizations (eg. ITU, CTU, PATU, APT, CEPT) to remove all barriers to the free movement of mobile satcoms which are essential to emergency and relief work. PAHO in particular has been able to persuade governments of most of its member states to allow free movement of Inmarsat satellite terminals in the Americas for combatting major disasters.

THE INMARSAT SYSTEM

There are three basic components of the Inmarsat system: the space segment, the land earth stations (LESs) and the mobile earth stations (MESs).

The Inmarsat Space Segment

The operation of the Inmarsat space segment, i.e. the satellites and the associated control facilities, is the responsibility of Inmarsat and is funded by its Signatories. Inmarsat uses its own four Inmarsat-2 satellites as the main operational satellites. Additional capacity is leased on seven other satellites. All of these are in geostationary orbits, serving four ocean regions for complete global coverage: the Atlantic West, Atlantic East, Indian and Pacific ocean regions. The next generation of satellites, Inmarsat-3, is being built by an international consortium. They will provide eight times as much satellite power as the current generation. The first launch is due in 1995.

Land Earth Stations (LESs)

The LESs provide an interface between the space segment and the national and international fixed telecommunications networks. They are generally operated by Inmarsat's Signatories. Many LESs provide a range of value-added services to their users, e.g. electronic mailboxes or access to e-mail networks. There are currently over 70 earth stations for various systems, with more being built or planned (see Fig. 1 for location details). An LES handles the calls and keeps records for accounting and the subsequent billing with Inmarsat, the Accounting Authorities, or in some cases, directly with the user. Each of the four ocean regions represents an independent but interconnected network.

Mobile Earth Stations (MESs)

There are over 31,000 Inmarsat MESs of all types in operation today. They are purchased, leased or rented from manufacturers, their agents, system integrator or rental agencies. Some Signatories have special rental or leasing arrangements for disaster relief teams. More than 20 companies throughout the world design and manufacture MESs which conform to Inmarsat technical requirements. Given the variety of the equipment available,

the user can choose a system which best meets his needs in terms of functionality, size, weight, power consumption, service, cost and delivery. For disaster relief and emergency assistance operations, either Inmarsat-A, Inmarsat-M, Inmarsat-B or Inmarsat-C could be most suitable. Table 1 contains a brief comparison of technical and economic parameters.

INMARSAT-A

There are now over 6,400 land-based Inmarsat-A MESs registered in some 135 countries. In addition to international relief organisations, the system is widely used by heads of state, government entities, agencies of the United Nations, radio, television and press, general commercial users, even private individuals. Portable and transportable Inmarsat-As are the proven, dependable system used by disaster relief teams for communications with their home base for tasks ranging from damage reports to supplies requests and personnel management.

Inmarsat-A terminals offer high quality telephone/fax/data, telex or high speed data (55/64 kbits/s) channels. The system provides the Inmarsat user with a very simple means of direct dialling to any telephone or telex machine throughout the world. In the other direction, terrestrial subscribers can call the Inmarsat transportable as easily as calling any other international number. Transportables can also communicate directly with each other. The recent growth of facsimile machines, electronic mailbox services and computer-to-computer data exchanges via telephone voice-band modems is now as common with transportable Inmarsat-As as in the office. Photos, slow-scan video and compressed video can be transmitted from terminals with the installed HSD/DHSD option. Larger antenna models enable lower cost communications and multichannel models with up to four channels are available.

INMARSAT-M

In response to demand for a smaller, lighter and cheaper mobile satellite telephone, Inmarsat has developed Inmarsat-M. This is a fully digital system designed to provide good quality voice, as well as fax and data transmission at 2.4 kbit/s. The Inmarsat-M terminal is lightweight (8-14 kg including a battery), and is cheaper to operate than Inmarsat-A. A multichannel version will be available in the near future.

Commercial telephone service is already available in all ocean regions and fax and data transmission services will follow later this year. Several manufacturers offer briefcase terminals, which are the smallest voice satcom terminals in the world. Inmarsat-M's portability, its ability to operate on battery power and its overall cost, makes the system a very strong candidate for emergency and disaster relief communications.

INMARSAT-B

Inmarsat-B, which just became available in 1993, is the digital successor to Inmarsat-A. It offers increased functionality at lower charges. This is particularly important for high

volume users, as well as many potential new ones, especially those requiring a wider range of new services based on its higher data rates.

The system provides very high quality voice, fax, and telex transmission as well as up to 16 kbits/s of data. One compact portable terminal weighs around 18 kg, which is comparable to the lightest Inmarsat-A terminal. Its advanced polymer case is watertight when packed, rainproof when deployed, and can withstand a 30-inch drop onto concrete. A high speed data facility is designed to be standard: it can support up to 11 simultaneous telephone channels or up to 20 data channels. This capability is especially helpful in situations where a large volume of calls and faxes need to be accommodated. Inmarsat-B will also be available in multi-channel versions.

INMARSAT-C

Inmarsat-C is a cost-effective alternative for situations where sending and receiving a written message is preferable to voice communications. Inmarsat-C is an advanced, flexible packet-data communication system using a small, low-cost mobile earth stations. Inmarsat-C systems can be carried either by an individual, or can be mounted on a vehicle. The briefcase or portable terminal is lighter, around 4 kg, with an integrated antenna. These terminals have directive high gain antennae to reduce power consumption, hence they can operate effectively with batteries. Inmarsat-C is so small and lightweight that it is now possible for a field team to carry their own system when they initially enter a stricken area. When combined with a small PC (even a palm-sized data organizer can be used!), Inmarsat-C can immediately provide the means for reaching headquarters with an accurate assessment of the situation and requirements. Received instructions can be displayed, stored in a memory or printed at a later time.

As of this writing there are over 3,500 land-based Inmarsat-C users. This system provides: two-way messaging and data communications on a store and forward basis; one-way position and data reporting; polling; and the Enhanced Group Call (EGC) broadcast service which is able to address specific groups of users. In disaster relief work, it is the means for sending damage assessment reports either in "free" or pre-coded format, and receiving instructions from the home base. The mobile versions in vehicles (with omnidirectional antennae) can send automatic position reports and can send and receive messages while on the move.

The system can provide both public and private (closed user group) access. The Inmarsat-C system interconnects with any terrestrial message or data network, e.g. telex and X.25 or via a modem with a telephone network. The mobile version can deliver a message to any fax machine. Soon, services based on X.32 and X.400, including e-mail networks such as Internet, will be available from several LESs. Data is transferred between the mobile and LES or vice-versa at an information rate of 600 bit/s. The data reporting protocol permits the user to send short messages of up to 32 bytes via a special channel at very low cost; this feature is especially useful for mobile unit or vehicle position reporting. Several companies are marketing complete kits for portable use based on the popular mobile terminals.

An Inmarsat-C terminal, coupled with sensors and operating with the data reporting and polling protocols, enables the satellite control and data acquisition (SCADA) system. The automatic SCADA terminals can provide tsunami, earthquake, tropical storm or flood warnings. They can be powered by solar panels, batteries or other power sources. SCADA systems can also help in remote control of flood-prevention systems, for example by activating flood gates.

WHAT THE FUTURE HOLDS

The continuous engineering and commercial efforts of the Inmarsat organization guarantee further improvements in size, cost and performance of all Inmarsat systems. Within the next two years, Satellite Paging is planned as a new worldwide system for inexpensively getting messages to people in the field as well as in urbanized areas. Smaller Inmarsat-M and Inmarsat-C terminals with upgraded capabilities will be possible when the Inmarsat-3 satellites are launched. For the 21st century, Inmarsat's Project 21 is looking into the development of small, low-cost personal communicators that would still offer global coverage.

CONCLUSIONS

The Inmarsat global mobile satellite communications system is ideally suited to supporting disaster preparedness and relief operations throughout the world for the following reasons: a) Inmarsat is independent from local telecommunications infrastructures and, with batteries or generator power supplies, Inmarsat terminals are self-sufficient and can be in operation within minutes of arriving at the site; b) Inmarsat provides unlimited communications as well as compatibility and is as effective in providing communications between two independent relief teams working in the same locality as it is in providing direct links to relief agencies and material suppliers anywhere in the world. All equipment approved to operate with the Inmarsat system meets common technical standards, thus ensuring operational compatibility in the field and internationally; c) Inmarsat equipment is so simple to use that, if necessary, it can be set up and operated by untrained crew using instructions provided with the units; d) Inmarsat equipment is compact and lightweight -- many models can be hand carried; and e) the Inmarsat system offers complete reliability because satellites provide the most reliable communications medium, one which is unaffected by atmospheric conditions or distance.

Table 1. Comparison of Inmarsat Systems

	Inm-A	Inm-B	Inm-M	Inm-C
Equipment cost (1)	US$25-45k	US$25-50k	US$12-20k	US$5-10k
Cost/minute (2)	US$7-9	US$4-5	US$3-5	US$1.00(3)
Overall min. weight	18 kg	18 kg	9 kg	4 kg
Battery option	no	no	yes	yes
Telephone	yes	yes	yes	no
Group 3 fax, max.	9.6 kbit/s	9.6 kbit/s	2.4 kbit/s	N/A(4)
Data typical rate	9.6 kbit/s	9.6 kb/s	2.4 kbit/s	0.6 kbit/s
High Speed Data	56/64 kb/s	56/64 kb/s	no	no
Short Data/Position report	no	no	no	yes
Multi-channel version	yes	yes	yes	no
Video transmission	yes	yes	no	no

(1) Equipment costs vary depending on manufacturer, model, type, options and place of delivery.

(2) Ranges shown are averages. Actual charges vary from LES to LES. Additional land line charges may be applicable. Discounts for off-peak, large volume users, multichannel and large antenna are available.

(3) The approximate charge shown is for 100 characters. Actual minimum charges are for 256 bits, i.e. 32 characters.

(4) Message delivery from a mobile terminal to a fax machine is widely available.

Figure 1

System Availability	Inmarsat-A	Inmarsat-B	Inmarsat-C	Inmarsat-M	Inmarsat-Aero
1. Nikea Canyon	●				●
2. Santa Paula	●	●	●		●
3. Laurentides					●
4. Southbury		●	●	●	●
5. Staten Island	●				
6. Tangua	●		●		
7. Goonhilly		●	●	●	●
8. Pleumeur Bodou	●		●		
9. Ausaguel					●
10. Blavand	●		●		●
11. Barum	●		●		
12. Fucino	●		●		
13. Elk		●	●	●	●
14. Peary	●				
15. Reisting	●		●		
16. Thermopiae	●		●		
17. Masdi	●				
18. Odessa	●				
19. Anatolia	●				
20. Ala	●		●		
21. Jeddah	●				
22. Boumehen	●		●		
23. Um-Al-Aish	●				
24. Arvi	●		●		
25. Bijing	●		●		
26. Nakhodka	●				
27. Kumaan	●				
28. Yamaguchi	●	●		●	
29. Singapore	●		●		●
30. Perth	●	●	●	●	●
31. Ganagara	●				

SPACE COMMUNICATIONS FOR DISASTER MITIGATION*

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INTRODUCTION

Thanks to recent technological advancements, modern satellite services offer wide (practically unlimited) coverage of the Earth, user-friendly and universal access and high reliability. Technological advances have spurred renewed interest in certain applications which had previously been considered ineffective. For example, the increase of on-board power/link efficiency has allowed the miniaturization of user terminals; system capacity has significantly increased and service costs have decreased.

Remote sensing and earth observation satellites, such as LANDSAT and SPOT, meteorological satellites, including those of the United States National Oceanographic and Atmospheric Agency (NOAA) and EUMETSAT, and communication satellites, typically mobile satellite systems (MSS), and very small aperture terminal (VSAT) systems, constitute the basis for effective disaster mitigation satellite systems.

Small low-earth orbit (LEO) satellite technology is also being investigated to see whether it can provide a cost-effective basis for implementation of a global search and rescue system. This technology, substantially derived from spin-offs from military applications for global warning/surveillance networks, appears to be rather promising because it allows quick, reliable communication/alert with light user terminals, by means of constellations of 6-10 small spacecraft covering the Earth. As a matter of fact, while satellites in a geostationary orbit (GEO) appear to be fixed with respect to the Earth, which enables three (or four, at most) spacecraft spaced 120° apart on the geostationary orbit to fully serve all the regions in the world, LEO satellites have a much shorter period of revolution around the Earth, so that they can only be visible from a given point on the Earth for a short period. Several LEO spacecraft, suitably offset in time/orbit, are then required if a real-time operation is requested. Conversely, the lower altitude of LEO satellites (typically 1,000 km as opposed to the 36,000 km GEO) permits more effective communication performance with lighter and less complex ground equipment.

This paper reviews the present situation in the field of satellite-based disaster mitigation systems (warning, alert, search and rescue, etc.), with a focus on the COSPAS/SARSAT system

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* This paper, which was presented at the United Nations Workshop on Space Communications for Development, held in Athens, Greece, 10-12 May 1993, does not necessarily reflect the views of the United Nations.

and the Global Maritime Distress and Safety System (GMDSS). The potential applications of these systems for the Mediterranean region is then discussed.

SATELLITE SYSTEMS FOR DISASTER MITIGATION

COSPAS/SARSAT

COSPAS/SARSAT is an international, cooperative, satellite-based location system for search and rescue (SAR) operations. It was first conceived, for terrestrial operations, by Canada in 1979. After this initial Canadian interest, the United States, the former Soviet Union and France, through the French space agency CNES, established a formal programme in 1986. As of 1992 there were 30 countries in the consortium.1/

COSPAS/SARSAT utilizes two individual space segments, one from Russia (COSPAS payloads, recently embarked on Kosmos spacecraft), and one from the United States, the Search and Rescue Satellite-Aided Tracking (SARSAT) payloads, which are embarked on NOAA polar orbiting satellites such as Tiros-N.

Table 1. COSPAS/SARSAT Parameters

COSPAS parameters	SARSAT parameters
• inclined polar orbit (83°)	• inclined polar orbit (99°)
• altitude 1000 km	• altitude 850 km
• revolution time 106 min.	• revolution time 102 min.

The individual satellites are offset in time, so that cooperative efforts are carried out to fully cover the whole surface of the Earth in less than three hours.

Various types of mobile terminals are utilized:

a) Emergency Locator Transmitter (ELT) on aircraft;
b) Emergency Position-Indicating Radio Beacon (EPIRB) on ships; and
c) Personal Locator Beacon (PLB) for individual search and rescue.

These transmitter can either be activated manually or automatically in the case of a crash or other accident.

The most relevant network elements are the Local User Terminals (LUT) which are earth stations receiving data from satellites @ 1544.5 MHz and which determine the location of distress

calls, and the Mission Control Centre (MCC) units which receive and analyze distress alerts and locations from the LUTs and then pass the information to the appropriate Rescue Coordination Centre (RCC).

Two RF beacons are utilized @ 121.5 MHz and 406 MHz. The 121.5 MHz signals are simply relayed by payloads (there is no on board storage/processing), and are only received on the ground if at least one LUT is in visibility at that time; the 406 MHz messages are processed/stored on board, and re-transmitted only when there are LUTs in range.

Doppler and Doppler Rate measurements are employed to detect the latitude and longitude of the beacon(s). The accuracy of the radio determination system is about 20 km @ 121.5 MHz and 5 km @ 406 MHz.

Global Maritime Distress and Safety System (GMDSS)

The GMDSS integrates all communication, distress and alert systems for maritime users.2/ By February 1999 all ships must be in compliance with GMDSS requirements.

The objective of GMDSS (due for implementation late in 1993) is to alert maritime SAR authorities ashore and to facilitate coordinated SAR operations with minimum delay. It is based on automated systems (both satellite- and terrestrial-based) which do not require specialists to send distress communications. Alerts are either activated manually by pushing a button on the vessel or automatically.

The GMDSS utilizes the following systems:

a) INMARSAT geostationary satellites:

- Standard-A (toll-quality voice, telex, facsimile, < 9 kbps data, high speed data, telex group call, (EGC);
- Standard-C (data messages, polling, data reporting, EGC, SafetyNET);

b) COSPAS/SARSAT polar orbiting satellites;

c) Maritime mobile services @ MF (415-to-535 kHz);

d) Maritime mobile services @ HF (4-to-27.5 MHz); and

e) Maritime mobile services @ VHF (156-to-174 MHz).

GMDSS will also provide several special purpose services:

a) Enhanced Group Call (EGC) SafetyNet: broadcasting of weather and navigation safety information to groups of ships equipped with either Standard-A or Standard-C user terminals;

b) NavTex: based on Narrow Band Direct Printing (NBDP) techniques to transmit Maritime Safety Information (MSI) - coastal water situations, weather forecasts, etc.;

c) Digital Selective Calling (DSC): increases ability of the distress message to be routed and received by including the identity of transmitting ship, nature of accident, position coordinates, time (incorporates NBDP features);

d) INMARSAT L-band EPIRB: same services as Cospas/Sarsat, it uses L-band and only guarantees instant alerting and relay of distress messages between latitudes of 70°N and 70°S; and

e) Survival Craft Radar Transponder: primary means by which a survival craft or EPIRB announces its presence by responding when interrogated by a shipborne or airborne (9 GHz) radar.

National Oceanic and Atmospheric Administration (NOAA) Satellites

United States NOAA satellites carry several payloads, including the SARSAT and ARGOS payloads.3/ The NOAA fleet includes both geostationary spacecraft (Geostationary Operational Environmental Satellites, NOAA-GOES) and low-earth orbit spacecraft (Polar Orbiting Operational Environmental Satellites, NOAA-POES). The primary applications for both types of satellites is weather forecasting and meteorology (standard meteorological readings in remote locations).

Data collection systems via NOAA satellites allow monitoring of sea conditions through measurements on ocean buoys, read-out of data from aircraft and balloons, relay of hydrological data on rivers level, and determination of snow thickness. Continuous S-band broadcast is provided for the international user community and anybody with a receiving station can access the data.

The previously mentioned ARGOS system, operated by CNES, permits satellite-based location within 350 m of fixed and moving platforms, and collection of environmental data. The platforms can be buoys, free-floating balloons, remote weather stations or ships which are equipped with platform transmitter terminals (PTT). The terminals have a 401.650 MHz uplink frequency. The PTTs collect and process relevant data and transmit them through NOAA satellites to command and data acquisition (CDA) stations that then process the data. More than 1300 ARGOS PTTs are operating worldwide.

SPECIFIC TELESPAZIO EXPERIENCE FOR THE MEDITERRANEAN REGION

ARGO System

In the early 1980s Telespazio designed, developed and engineered the ARGO Project for the Italian Ministry of Civil Protection. The system provides real-time monitoring of environmental data (seismic, volcanic and hydrogeological) through 110 fixed, VSATs scattered across the national territory of Italy, and, through the use of 12 transportable stations, facilitates the restoration of emergency communications whenever required. Both sets of facilities are connected via EUTELST spacecraft to the Operational Civil Protection Centre of Rome and to a master station at Fucino.4/

Telespazio is also responsible for the procurement, testing, installation and operation of the entire system on behalf of the Ministry of Civil Protection.

The same type of architecture can be adapted to fulfill requirements of data collection/monitoring and emergency communications (e.g. restoration of communication links after a catastrophe, or in any situation requiring the rapid establishment of communication facilities) in any country/region in the world.

Small Satellites (TEMISTAT)

Telespazio is developing a commercial "micro" satellite system called the Telespazio Microsatellite (TEMISTAT) providing data collection and distribution from/to autonomous networks. The system is comprised of two microsatellite units (35x35x35 cm and about 30 kg each), which allow the implementation of a low cost satellite system based on a TDMA/SCPS access scheme. The expected operational life of each satellite is five years. A Mission Control Centre and two different types of terminal Data Collection Centre terminal and a User Terminal are also part of the system. This kind of architecture is well-suited for both developed and developing countries for provision of services across geographical regions where a multitude of remote terminals with limited throughput are available. Utilizing the microsatellite technology, a space-based data collection and distribution network may be less expensive than traditional (large) satellites.5/ (See annex for more information about on TEMISAT.)

In the early stage of operations the service will be provided, at least on a daily basis, to private and public users located in Italy and the surrounding European and Mediterranean region. It is our intention to gradually extend the service to other geographical regions, including South America and the Pacific Rim.

As already noted, whenever a real-time operation is requested, typically in the warning/alert systems outlined in this paper, a constellation of spacecraft is required so that at least one satellite is always in range. Thus, implementation of global warning/SAR services can be achieved through the use of constellations of 6-10 small spacecraft covering the entire Earth.

In the present (limited) configuration of these systems, data are acquired and collected through earth-based sensors/terminals, then temporarily stored in ground systems and logged by autonomous terminals until the uploading request (polling) is received from the TEMISAT spacecraft. Once the data are received, they are transmitted from TEMISAT to User Collection Centres.

The first TEMISAT unit was launched from Plesetsk, Russian Federation on 31 August 1993 along with the Meteor-2 Satellite (nominal LEO altitude 950 km, inclination 82.5°, orbital period approximately 110 minutes) by a Russian H-Tsyklon launcher. The second unit, manufactured together with the first satellite, will be launched in approximately three years to assure service continuity and to increase in-orbit capacity.

Mediterranean Maritime Risks and Emergencies System (SERIMAR)

The objectives of SERIMAR are to:

a) provide timely evaluation of accident risks in the Mediterranean Sea;

b) provide decision and management support for post-disaster relief operations in order to minimize the economic and environmental effects of disasters; and

c) provide support to the evaluation of economic and environmental effects of disasters.

The system approach consists of:

a) monitoring of sea conditions, coastal and atmosphere;

b) implementing simulation models for (man-made) risk forecast;

c) timely transmission of risk information to users; and

d) identification/localization of hazardous loads/routes.

The main elements of the SERIMAR are:

a) utilization of atmospheric, meteorological and oceanographic data, coastal belt topography, port infrastructure (data are gathered from existing national and international data banks, associated with Earth observation satellites such as ERS-1, which are able to detect the wave height, wind direction, etc.);

b) implementation of numerical models (software) to simulate/predict the risks for environmental disasters (e.g. effects of petrol leakages due to ship collisions) in specific areas;

c) utilization of terrestrial-based (e.g. coastal radars) and satellite-based Global Positioning System (GPS) localization techniques;

d) utilization of Mobile Satellite System (MSS) communications (via INMARSAT); and

e) coordination centres (e.g. civil protection departments, international RCC centres).

CONCLUSIONS

The observation of Earth from space constitutes an invaluable and precious tool for forecasting and preventing environmental disasters. The combination of remote sensing and communication satellites provides the ability to effectively solve the problems of distress alert, localization and rescue activation.

Small satellite technology (e.g. TEMISAT) allows cost-effective implementation of global warning/SAR services by means of constellations of 6-10 small spacecraft covering the entire Earth.

Cooperation between terrestrial and satellite systems is probably the best combination of advanced search and rescue tools (e.g. air and maritime traffic monitoring via terrestrial radars and satellites such as GMDSS).

In light of the above, it is evident that space communications are extremely viable for disaster mitigation, and as such they should receive increasing interest from concerned organizations at both the national and international level.

NOTES

1. Gallagher, Brendon, (ed.), "Never Beyond Reach," INMARSAT, 1989.

2. ibid.

3. NASA Goddard Space Flight Center, "Tiros-N/NOAA," January, 1991.

4. G. Martinell, B. Driolli, C. LaRocca, and F. Menclotti, "ARGO: A satellite Telecommunication System for Civil Protection and Territory Monitoring Purposes," 8th International Conference on Digital Satellite Communications (ICDSC-8), Pointe-à-Pitre, Guadeloupe, April 1989.

5. F. Ananasso, G. Rondinelli, P. Palmucci, B. Payesi, "Small Satellite Applications: A New Perspective in Satellite Communications." 14th AIAA International Communication Satellite Systems Conference, Washington, DC, March 1992; B. Pavesi, G. Rondinelli, and N. Balteas, "A Microsatellite System for Autonomous Environmental Monitoring Service," 6th AIAA/USU Conference on Small Satellite, University of Utah, September 1992; and F.

Ananasso, "Small Satellites for Mobile and Environmental Data Communications: Effectively Solving Economic, Social and Technological Issues," 15th Annual Pacific Telecomunications Conference, (PTC '93), Honolulu, HI, January 1993.

ANNEX

Telespazio Micro Satellite System (TEMISAT)

The TEMISAT system is composed of three main segments:

(i) A Space Segment consisting of two micro-satellites (each with dimensions of 35x35x35 cm and weighing about 30 kg), which implements a low-cost satellite system based on a TDMA/SCPC access scheme. The expected operational life of each satellite is five years.

The major characteristics of the satellites are:

- Store-and Forward service (2.4/9.6 kbps throughput)
- VHF/UHF Operation
- Direct or On Request Access
- High Reliability/Full Redundancy
- On-Board Data Demodulation, Storage and Handling

A semi-passive attitude control system is present (magnetic stabilization to the local magnetic field of the earth), whereas power generation is assured by six solar panels mounted on the external spacecraft surface.

(ii) The Ground Support Segment, consisting of a Mission Control Centre. This Centre processes, manages and stores the mission data, and prepares the user routing matrix that contains the polling sequence, the synchronization and the addressee identification codes.

(iii) The User Segment, consisting of two different types of terminals:

- User terminal, and
- Data Collection Centre terminal.

The user terminals are connected to the block of sensors, which are set for acquiring the measurements and for storing them temporarily. More than 1,000 user terminals are planned to be used in the final network configuration, each one being capable of serving several sensors.

The Data Collection Centre is able to receive the down-link data flow from TEMISAT corresponding to the information collected from the user terminals belonging to its closed user group (CUG). It is also envisaged that during the transmission of command packets from each Centre to the satellite, these commands will be delivered to the addressed user terminals inside the polling packets.

TRACKING SEVERE STORMS AND WEATHER PATTERNS*

C.E. Berridge
Coordinating Director
Caribbean Meteorological Organization

Methods used to track severe storms and weather depend on the level of sophistication in the services with those responsibilities. I will confine myself to systems for tracking severe storm and weather patterns which are used in the seven Caribbean Meteorological Organization (CMO) forecast offices. I assume that this talk is not expected to be confined to tracking based only on space-based systems. A better appreciation of the subject may be gained, if you would bear with me, as I attempt to outline briefly the operational practices of CMO forecast offices responsible for these activities, as these are intimately tied to being able to track the systems. I am unaware of the specialized meteorological expertise of the audience, as a result, what I propose to outline may not be news to many of you, or may even be considered dated. Hopefully to others it may serve to give a clearer picture of how we operate.

Meteorology is based on the treatment of the atmosphere as an ideal gas, and wind flows are treated like fluids. Their behaviour in a laboratory as a result of changing parameters are predictable. In practice, as we all know, it is different, so that local experience, combined with science, plays a significant part in the results. Meteorology requires weather data from as wide an area as possible. Today with high speed computers available in the more advanced forecast centres, weather data is collected from all over the globe and fed into computers, from which analyses and specialized products emerge. These are transmitted to smaller services and fine tuned locally to assist in the generation of local output to meet requirements. We know that all global weather patterns are inter-related. It thus becomes necessary that all weather reporting must be in an agreed format for global use.

A Caribbean meteorologist who does not know Chinese can nevertheless read a Chinese weather observation and know what the report means. A low pressure system off Africa could affect weather in the Caribbean, and evidence of the major influence of such phenomena as the El Niño on weather over significant parts of the world, is now well recognized. One sees from the programme that there are speakers who will go more extensively into some of these areas. In CMO offices, by no means as sophisticated as those with high speed computers, we limit the area of weather data coverage to include parts of West Africa, parts of the Northern and Southern Atlantic Oceans, most of the Americas and of course data from the Caribbean. These include information from land, ships at sea, aircraft, radar and satellites. The parameters reported from a land station include present and past weather, wind velocity, direction and speed, temperature, dew point, visibility, barometric pressure and its change and tendency over the last three hours, cloud cover, amounts, types and heights of the cloud base.

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* This paper, which was presented at the United Nations/European Space Agency Regional Workshop on Space Technology and Applications to Prevent and Combat Natural Disasters, held in Mexico City, Mexico, from 27-30 September 1993, does not necessarily reflect the views of the United Nations.

Upper-air stations report heights of barometric pressure levels, temperatures, humidity, wind direction and speeds at different altitudes, and height of the tropopause layer in the vicinity of the observation. Ships include reports of wave height, direction and frequency of swells along with the parameters listed earlier.

Good telecommunication systems are needed to make these data available, and the World Meteorological Organization (WMO) Global Telecommunication System is designed to achieve this. Much of this is done by satellite. In CMO forecast offices these data are plotted on surface and upper-air chart and analyzed by the forecaster to provide a three dimensional picture of the weather patterns for the time of the map data. Combined with earlier analyses of similar kinds, continuity and changes in the systems are evident.

Fronts (air mass discontinuities), areas of low and high pressures, troughs, etc, are depicted in these analyses. These are the basic tools for combining science and experience in fulfilling services obligations to a wide array of users. Additional data inputs including radar, satellite and subsequent observations after the chart time are combined with analyses to provide relevant products.

In the Caribbean there is a wet and dry season, coinciding with the northern summer and winter. In terms of severe weather, the hurricane season in the summer is the period of the greatest severe weather threat to the region. The WMO has a Hurricane Committee for the region which coordinates its definitions and relevant activities to deal specifically with severe weather systems. The Miami Hurricane Specialist Activity Centre is the focal point for the provision of their computer-derived forecast track products during times of active weather in the region, and also serves as the coordinating centre for warnings issued by stations charged with responsibilities of warning their various communities. The close proximity of the islands to each other and the passage of a severe weather system with widely varying warning systems, is a recipe for chaos. Hurricanes are not the only form of weather that create problems in the region. Heavy rains from the intertropical convergence zone, easterly waves, and slow moving thunderstorms create floods. High winds associated with thunderstorm activity destroys banana plantations, and isolated convective cumulonimbus clouds sitting over an area also cause local flooding and wind damage from downbursts.

Winter storms moving over the Atlantic create high seas which do damage to low lying coastlines even as far south as Guyana and Surinam. The occasional winter cold front moving south can cause strong winds and heavy rainfall, especially in the northern parts of the Caribbean and Central America.

The CMO has assigned certain forecast offices responsibility for offering bulletins, advisories and warnings to other nearby Member States of the organization during periods of severe weather. All countries cannot afford to operate forecast offices, nor do we need duplicate facilities. In order to fulfill these obligations, however, the existing forecast offices must develop a level of expertise in tracking, and forecasting development of these systems.

The CMO operates a radar network comprised of stations located in Guyana, Trinidad and Tobago, Barbados, Antigua, Jamaica and Belize. Radars are an indispensable tool for detecting and following severe weather systems within their range, and in our region with many islands in close proximity to each other, properly functioning radars are very necessary

for minimizing the area for which warnings can be hoisted. The economic implications of shutting down a few islands unnecessarily does not make for amicable relationships between the meteorologists and the community. The radars were strategically located in these places to form an overlapping fence to detect and track the passage of severe systems approaching the CMO area. These units are over 23 years old and have now outlived their anticipated lifetimes, and spares are almost impossible to obtain. New technology has made them almost obsolete. The units in Guyana and Antigua are unserviceable. The region's economic circumstances do not permit replacement of these units, and we are diligently pursuing their replacement through technical assistance. Interested parties should feel free to contact me.

CMO forecast offices assigned severe weather warning tasks have satellite WEFAX reception capability. Orbiting satellite photos are copied as they pass overhead, and enhanced pictures from the geostationary satellites are available. Systems are followed fairly effectively from these photos, and combined with the aforementioned analyses, reasonably good skills in tracking have been developed in the region. Satellite observations play a major role in meteorology because they provide cloud pictures and data over vast areas from which previously there was nothing. The oceans east of the Caribbean islands, from which most severe weather emanates, are not very busy sea lanes, so few ship reports are routinely available. When there are reporting ships in areas of severe weather, they very soon leave for very obvious reasons. The various combinations of data available to the meteorologists must be synthesized to provide a basis for the provision of the information for users. At times the information seems contradictory. Experience then becomes a major factor in the determination of what should be accepted or ignored.

Once a system with the potential to develop into severe weather is observed, close attention is paid to it, and its development and track very carefully monitored. Over the ocean, satellites are the primary tools used for tracking and monitoring the development of systems.

Techniques have been developed to recognize cloud brightness winds, upper-air profiles, temperature distribution and cloud formations as evidence of the changes in the weather systems. Depressions, easterly waves, the Inter Tropical Convergence Zone (ITCZ) and other cyclonic systems generally exhibit typical visual characteristics. The typical comma shaped cloud mass with the cloud-free eye in a well developed hurricane, is well known. Not all systems reflect these well known patterns. Radars play a more important tracking role as the systems come within range, and also in making very short range forecasts of severe weather from isolated clouds, not necessarily associated with a major weather system. They are vital in flash flood warning services. As stated earlier, because our Member States are so close to each other, in a major hurricane, its cloud system could cover most of the eastern Caribbean islands. That does not mean that all of them will be subjected to the same intensity of wind, weather, or storm surges. It becomes important to be able to delineate those locations which will experience the differing levels of the storm effects. Being able to monitor the system constantly with radar once the system is within range, direction and speed of motion are more obvious, and comprehensive and more detailed warnings are possible.

In severe weather systems, there is the added facility of hurricane reconnaissance aircraft, provided by the USA. These aircraft are well instrumented, and have experienced

observers and crews. They record and report actual conditions within the hurricanes. It is the only accurate measure of central barometric pressure, temperature, and wind profiles in the system when it is over the ocean and these are important data inputs in the determination of the intensity and severity of the damage potential of the system. It is a very expensive but vitally important database for which not enough recognition is paid to these daring crews, and the efforts of the USA to provide these services is greatly appreciated in our region. There are experiments underway to use remotely-controlled aircraft, which if successful, would cut costs and the potential danger to crews.

Mention was made of regional capabilities to receive satellite data through WEFAX systems in the region. This system of reception is vitally important, but also has limitations, in that data is available only when the orbiting satellite passes overhead, or the photos from the geostationary satellites are copied and enhanced and retransmitted from the main ground stations.

WEFAX does not offer a continuous monitoring capability in the same way that radar does. Photos are available about every two hours. The margin of error in pinpointing the location of centres of cyclonic systems, an important facet in all warnings using WEFAX techniques, is roughly 60 km depending on the satellite being monitored, the angle of the unit as it passes over, etc. It must be remembered that the centres of well developed cyclones are about 10 to 20 kms. These errors can be of the same order as the distance between some of our islands. An error in the initial positioning of the centres could lead to increased errors in final land fall prediction hours later, and could influence the status of the warnings issued to countries in the path of the system.

Direct Satellite Ground Readout Stations copy satellite photos more frequently, approximately every 30 minutes, but are somewhat more expensive than other types of stations. At present, CMO forecast offices do not have them. Most of us have seen the very impressive weather broadcasts on some TV stations with moving systems clearly depicted. This is possible with ground readout centres, and film loops can be made of the photos received over a period of time, which when projected reflect the systems in motion. Very much use is also made of computer-enhanced pictures of satellite photos, in which colour scales reflect temperature differences and altitudes in parts of the weather systems. This serves to depict more clearly the structure and distribution of weather in the systems. WEFAX does not offer these capabilities. We are undertaking a major overhaul of our regional telecommunications systems, using very small aperture terminal (VSAT) technology which will increase transmission and reception speeds, improve the quality of the broadcasts, and provide more analyzed weather products and information, including satellite data, to our forecast offices. Computer work stations are part of the package and the level of enhancement and variations will depend on the amount we are prepared to spend on the software. The new systems are expected to be in place by late summer 1994. I am unable to tell you exactly what type of software is going to used. It is planned to introduce units which hopefully can be expanded to meet the inevitable improvements in technology.

The USA as the WMO Regional Main Telecommunications Network centre for this region, is the major contributor to this new program. Germany, France, the United Kingdom and Canada are also donors. It has been a project which the speaker has long been hoping to introduce to the CMO, and together with WMO and the Hurricane Committee, it is now

underway, not only for the CMO, but for most of the Members in the region.

We publicly thank them. This will eliminate the manual plotting and much of the analyses mentioned previously. Forecasters will now have more time to deal with the science. There will be analyzed products and the need to adapt and fine tune them for regional use will still be necessary. It should go a long way toward enhancing our ability to monitor and track weather systems likely to affect the region. Long range forecast products will be available. Our regional forecasters are already pursuing a program, thanks again to the USA, in which they are attached to the NOAA Numerical Meteorological Centre in Washington, working side by side with their experts in the development of these products. We are hoping that their tropical expertise will contribute to the development of more accurate long range prediction techniques for the Caribbean and tropical areas. The existing products are acknowledged to be much less accurate for the tropics but all reports to date indicate that the centre is pleased with the progress of the programme. A similar programme is now being put in place by the Montreal Centre in Canada. We are equally grateful for this opportunity to expose our staff to these operations. Looking back over the years, when I was an operational forecaster and such technology did not exist, fortunately, the economic value of meteorology did not loom so large in public awareness. There existed an almost fatalistic public acceptance of the wrath of nature, or whichever God one accepted. There was less development taking place and economies were in a much more relaxed mode. There was less to lose, even though we could afford it less. The concept that time was money, had not permeated the inner consciousness of too many people. Today with increased housing stocks, and development of agriculture and industry we now have more to lose, and the economic implications of any setback, including that due to severe weather systems, will impact more heavily. The role of meteorological services has increased and we have to improve our watch and warning services to mitigate effects and minimize the loss of lives. Should our worst fears about global climate change become reality, meteorology will have an even greater role to play. We are attempting to prepare for these roles. Our regional training facility at the Caribbean Meteorological Institute (CMI) has, and continues to provide well trained staff to the region. A nucleus of experienced staff, familiar with modern techniques resulting from attachments to advanced centres and seminars exists in the CMO. Given the proper tools, we have the capability to meet increasing demands for services.

One has to emphasize the important role that radar and satellite technology has played in the realm of meteorology, especially for tracking severe weather patterns. Space-based technology has enhanced our telecommunications, which are fundamental to rapid exchange of vast amounts of meteorological data. It has opened vistas to hitherto unknown weather development patterns over vast areas of the globe, as well as shown them from a different perspective. It has enhanced our capability to monitor, track, predict and warn with a greater degree of accuracy. The results of which, notwithstanding recent major severe weather events in our area, have shown impressive reductions in loss of lives. Advances in the development of new technologies, will undoubtedly take place in meteorology, which in turn will improve the quality of our services to the public. Services must be kept abreast of these developments, and acquire state of the art technology in the field if we are to fulfill increasing demands on our services. The link between our regional economies and the acknowledgment that severe weather is the major natural disaster in the Caribbean, demands that we continue to hone our skills in the provision of better severe watch and warning services to the region. I have attempted to deal with the topic in the broadest possible terms, because I believe that the

audience consists of a wide array of disciplines. The meteorological experts here, one hopes have recognized this. Had this been another forum, the topic would have been dealt with in an entirely different manner.

Over many years of dealing with severe weather watch and warning services in the region, and aware of the resulting negative impacts on regional economies, it is very gratifying to note the expanded interest of other disciplines in these critical areas. Our services welcome these developments, and are very pleased and willing to cooperate in whatever way we can, for we recognize that warnings, no matter how good, are not enough. There is need for a whole host of other services and disciplines, if we are to mitigate the effects of these natural disasters.

MONITORING OF, AND EARLY WARNING ON, THE ONSET OF THE "EL NIÑO" CLIMATOLOGICAL PHENOMENON*

Manuel Valverde
SENHAMI
Peru

The term "El Niño" ("The Child") or "El Niño Cristo" ("The Christ Child") was used during the last century by fishermen in northern Peru to describe the warm waters that recurrently appear off the coast of that country towards the end of December, a time that is associated with the Christmas season.

Today, the accepted terminology speaks of an equatorial countercurrent that moves into the region in question.

The El Niño phenomenon refers to an anomalous situation in the interaction between the atmosphere and ocean, involving changes in the climatic system on a regional and global scale. Such an event is characterized by an abnormal warming of the waters in the eastern equatorial Pacific as a consequence of a transfer of heat and water mass from the western sector, to the initial accompaniment of rainfall in the north-eastern region (Peru).

The Scientific Committee on Oceanic Research (SCOR), Working Group 55, has defined the Niño in the following terms: the appearance of abnormally warm waters along the coasts of Ecuador and Peru down to the latitude of Lima (12°), during which non-average sea surface temperatures are recorded by at least three out of five coastal stations within a standard deviation over a period of four or more consecutive months.

The Niño event is a non-cyclic, recurrent phenomenon and is associated with what is known as the southern oscillation, being commonly referred to in today's literature as El Niño and the southern oscillation, or the ENSO phenomenon.

During the positive phase of the southern oscillation the atmospheric pressure is higher in the eastern sector of the Pacific, being associated with a freshening of the trade winds, upwellings along the coast, and a greater mass of water in the western sector (Oceania). A characteristic positive feedback process leads to an intensification of the zonal thermal gradient and a strengthening of the Walker circulation cell. On the other hand, during the negative phase of the southern oscillation the atmospheric pressure gradient decreases, the trade winds fall off, and a west-to-east surface circulation develops, resulting in a weakening of the Walker circulation.

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* This paper, which was presented at the United Nations/European Space Agency Regional Workshop on Space Technology Applications to Prevent and Combat Natural Disasters, held in Mexico City, Mexico, from 27-30 September 1993, does not necessarily reflect the views of the United Nations.

Simultaneously, the area of intense atmospheric convection (rising air associated with heavy cloud cover and precipitation near 160° E in the equatorial region) grows larger and moves towards the east of the international date-line (180°).

An intensification of the Hadley circulation is also observed, with a strengthening of the high-altitude westerly winds over the subtropical sectors of the Pacific.

Increased atmospheric activity shifting towards the south of the intertropical convergence zone (ITCZ) is observed, along with a heating of the troposphere coupled with seasonal variations in the altitude of this layer, and a movement of the jet stream towards lower latitudes.

Other meteorological characteristics of the phenomenon are high subtropical pressures, atmospheric front activity in mid-latitudes, and frequent atmospheric blocking.

The explanation for the way the phenomenon operates lies in the wave theory regarding the propagation of sea surface temperature (SST) anomalies. This theory describes the response of the ocean surface and the behaviour of the thermocline to changes in trade wind patterns along the equator. A reduction in the intensity of the trade winds in the central Pacific produces a reduction in the maximum volume of upwelling water and a lowering of the thermocline. This perturbation of the thermocline propagates eastward in the form of ocean waves known as Kelvin waves, which take about two months to reach the shores of South America. The phenomenon manifests itself in a lowering of the thermocline, reduced upwelling volumes of sea water, and the onset of above-average SST values as well as above-average sea levels in the eastern sector of the Pacific (South American coasts).

In this propagation of anomalies along the equator, the Kelvin waves are joined by Rossby waves, which move in a westerly direction and towards the poles.

Observations and the analysis of typical SST anomaly fields and winds during a number of Niño events have led to the identification of four stages in the evolution of a typical or canonical Niño.

(a) Precursor phase. This phase occurs during the spring in the southern hemisphere and is characterized by a positive phase in the southern oscillation, intense trade winds, and sea-level readings that are above normal in the western sector of the Pacific and below normal in the eastern sector. Temperatures are slightly above average on the sea surface towards the west and, below the surface, towards the east of a line corresponding to 160° east longitude.

(b) Phenomenon establishment phase. This phase occurs at the beginning of the southern hemisphere summer and is characterized by a significant fall in the strength of the trade winds between Indonesia and the international date-line (180°), a rise in sea surface temperature in the central Pacific, an intensification of convection activity, and an increase in rainfall. In certain coastal areas of Ecuador and along the coast of Peru, the SST begins to rise, as does also the temperature in the lower troposphere.

(c) Growth phase. This phase takes place during autumn in the southern hemisphere. The above-average SST values are highest along the coasts of South America, where they are accompanied by a rise in sea level and a lowering of the thermocline. These higher-than-average sea surface temperature values rise even further and spread to the entire tropical sector of the Pacific east of the 160°meridian. Accompanying this, there are unusual readings for the westerly winds around the 180° meridian, intensified convection activity over much of the central Pacific (moving eastward), and a weakening and breaking up of the Walker circulation. These unusual conditions continue for the rest of the year, although there is a decline in the SST off the coast of South America. The southern oscillation attains its peak value during the negative phase.

(d) Build-up and terminal phase. Beginning in the last month of the year, the trade winds start to return to normal west of 180° longitude and the sea surface temperature starts to fall. Along the Peruvian coast this temperature, after sinking to a relative minimum during the southern hemisphere winter, begins to rise to values below those recorded in the autumn (growth phase). Subsequently, there is a decline in the SST, accompanied by lower-than-normal values that extend westward. The Niño cycle ends some 18 months after the onset of the phenomenon, with pressure at Darwin and Tahiti nearly normal.

The current Niño event differs from the typical behaviour described above.

MONITORING

If the Niño phenomenon is to be monitored, its physical mechanism, both atmospheric and oceanic, needs to be understood.

Attention must be paid to the early signs in the form of climatic anomalies that are often observed ahead of the precursor phase. As examples, we might cite the intense rainfall recorded in Chile and, at the same time, locally in the northern hemisphere.

Account must also be taken of the climatic studies that have been carried out by a number of countries and that describe the climatic anomalies associated with the Niño phenomenon.

At the present time, the equatorial Pacific has been conventionally divided into regions designated as follows: Niño regions 1 and 2 (from 90° W eastward, between the equator and 10° S), Niño region 3 (90° W — 150° W and 5° N — 5° S), and Niño region 4 (sector between 150° W and 160° W and 5° N — 5° S), the purpose being to monitor sea surface temperature indices and any anomalies that may occur in these indices within the regions so delineated.

Another important indicator is the so-called southern oscillation index (SOI), which reflects anomalies in atmospheric pressure at sea level, and the calculation of which is based on the normalized pressure difference between Tahiti and Darwin. This index is associated with a cold event when it is positive and with a warm event when it is negative. During a negative phase in the southern oscillation there is a zonal decline in the pressure gradient

along the equator as a result of the higher-than average pressure values in the eastern sector of the Pacific and the lower-than-average pressures in the western. These changes produce a decrease in the intensity of the trade winds and in the volume of upwelling water, with consequent above-normal SST values and a weakening of the Walker circulation.

The atmospheric convectivity index in the central Pacific is calculated on the basis of long-wave radiation emission (LWRE). During a *Niño* event negative LWRE values are recorded, along with an intensification and easterly drift of the intense convection core in the central Pacific. The normalized LWRE index is established in the region between 5° N — 5° S and 160° W and 160° E.

The LWRE index is used to identify zones of intense convection, which is associated with a heavy cloud cover and abundant precipitation.

Wind indices, near the surface and at high altitude include normalized wind indices of 850 millibars (mb) for the easterly circulation and of 200 mb for the westerly circulation are recorded.

Sea-level anomaly indices are also important. During a Niño event above-normal sea levels are observed in the eastern sector of the equatorial Pacific, and below-normal levels on the western sector. A converse pattern is associated with the Anti-Niño phenomenon.

THE NIÑO/SOUTHERN OSCILLATION PHENOMENON IN RECENT MONTHS

In June 1993 temperature values more than 1.0° C above normal in sea surface temperature were observed over large areas of the eastern tropical and subtropical Pacific.

There was a decrease, however, in SST anomalies during June in the eastern equatorial Pacific, as indicated in the SST indices for Niño regions 1+2 and 3, unlike the index for region 4, which remained similar to that observed in May. Intensified atmospheric convection persisted over the western and central equatorial Pacific, and also in the northern region of the eastern equatorial Pacific, where the waters continued to be abnormally warm. Lower-than-average convection was observed in the Philippines and over much of Indonesia. The southern oscillation index (SOI) decreased to -1.4, June being the ninth consecutive month during which this index was negative.

Atmospheric pressure patterns at sea level displayed lower-than-average values in the eastern tropical and subtropical Pacific. Higher-than-average sea-level pressure values were recorded in Australia and in the tropical Atlantic, this having been the prevailing pattern during most months of the last three years. This kind of untypical behaviour has been associated with below-normal reductions in the intensity of the easterly equatorial winds over the Pacific.

In recent months the depth of the thermocline (the narrow layer in the ocean separating the warm waters of the surface from the deeper, cold waters) has been quite shallow in the central equatorial Pacific, although a return to near-normal depth has been observed in the case of the 20° C isotherm. Temperatures remained above average in the surface layer of the

ocean to a depth of approximately 80 m in a region extending from the east of the international date-line to the coasts of South America.

The intensity of the Niño/southern oscillation phenomenon has been moderated by the annual cycle, especially in the eastern tropical Pacific. The Niño tends to attain its maximum intensity (mature phase) at that time of the year when the sea surface temperature in the eastern equatorial Pacific is close to its seasonal peak (March—May).

In the last two years the mature phase of the Niño/southern oscillation phenomenon has coincided with the end of the summer and autumn seasons, as reflected in the thermal and pluviometric patterns that are typical of this warm event.

During June 1992 there was a rapid decrease in anomalous SST readings in the central and eastern Pacific because of the normal establishment of a "cold tongue" in the eastern Pacific Ocean. Nevertheless, higher-than-average sea surface temperature values were recorded near the equator in the vicinity of the international date-line (180°). At the end of 1992 atmospheric convection intensified in the vicinity of the regions of abnormally warm water in the central equatorial Pacific, and there was also an abatement in the strength of the trade winds.

SST values continued to be above average in the eastern tropical Pacific, peaking in May 1993. In June 1993, as in June 1992, those anomalously high sea surface temperature readings began to fall as a consequence of the re-establishment of the cold tongue.

In general, the last three years have witnessed higher-than-average SST values in the central equatorial Pacific region, while the trade winds have remained weaker than usual and the southern oscillation index has been predominantly negative. These patterns continued in June with no apparent indication of a return to normal. In this connection, we might mention that during the second week of July above-average SST values were recorded in several areas in Peru, between Tumbes and Chimbote, from +1.7° C to +0.6° C, and in Callao +0.9° C, while in the south (Moquegua) the sea surface temperature was -0.4° C below average.

The conditions characteristic of this warm episode became less marked during the month of July. There was a decrease in sea surface temperature anomalies and a freshening in easterly winds over much of the tropical Pacific. Near-normal eastern equatorial winds were measured over the entire Pacific, July being the ninth consecutive month during which values were lower than average. The high SST readings continued to decline significantly in Niño region 3 with the climatic establishment of the cold tongue. Nevertheless, there were continued significant above-average SST readings (close to +1° C) in Niño region 4 (eastward from the international date-line to a longitude of 160° W) and along the western coast of South America. Intensified atmospheric convection continued along the equator near the international date-line, marked by abnormally warm water in that region. Throughout the rest of the tropics, convection activity was near normal during July.

Despite the return to near-average values for the easterly equatorial winds, all the sea-level pressure anomaly patterns remained similar to those observed during recent months.

Below-average sea-level pressure values continued in the eastern tropical Pacific, while abnormally high values were observed throughout Indonesia. Consistent with these patterns, the southern oscillation index was again negative (-1.1).

The current warm episode, which developed in mid-1991, reached its mature phase at the end of that year. Mature-phase conditions continued until mid-1992, when the equatorial easterlies returned to near-average intensity and the untypical sea surface temperature values in the eastern and central equatorial Pacific began to turn negative. The current observations are similar to that development pattern.

In August the above-average SST readings decreased in the eastern and central equatorial Pacific. Oceanic conditions began to normalize. Nevertheless, SST values remained about 1.7° C above normal along the equator and in the vicinity of the international date-line (180°). Tropical atmospheric convection was near normal in the eastern Pacific region and slightly intense to the west of the international date-line. The trade winds were weaker than normal. The southern oscillation index stood at -1.4. Non-typical values were observed in atmospheric pressure at sea level, these being below average in the eastern sector of the tropical and subtropical Pacific and above average in the regions between Australia and Asia and also in the tropical Atlantic.

Off the coast of South America the sea surface temperature continued to exhibit higher-than-average values: +0.5° C at Baltra, Ecuador, and Callao, Peru and +1.0° C at Puerto Chicama and Chimbote, Peru, accompanied by somewhat higher-than-normal air temperature readings over much of the western coastline of South America.

There was a moderate rise in sea level as measured at the stations at Baltra, La Libertad, Ecuador, and Callao, Peru.

FORECAST

At this time there is evidence of a trend towards the normalization of atmospheric and oceanic conditions, especially in the eastern region of the tropical Pacific and along the Peruvian coast. In this latter area the SST was recorded at about 0.5° C over its climatological average during the first 20 days of September. Nevertheless, there is a persistent negative phase in the southern oscillation and some weakening in the intensity of the trade winds, which are inconsistent with a return to normal, along with a number of similarities to conditions observed last year. We might recall, in this connection, that there was a recurrence of the non-standard values in November 1992, triggering a continuation of the 1991-1992 Niño, a fact that suggests that there is not yet any clear pattern of normalization.

On the other hand, forecasting techniques such as the canonical correlation analysis (CCA) predict the continuation of above-average values, in an area roughly approximating Niño region 3, into the early months of 1994.

The Cane Zebiak forecasting model indicates that the surface temperature of the sea in Niño region 3 will be near normal at nearby stations, while the coupled (NMC) model forecasts a decrease in the high SST readings in the equatorial Pacific region over the next

few months (into the early months of 1994). This last model, however, points to a persistence of above-average SST values near the international date-line (equatorial zone).

If the anomalies associated with the Niño continue to develop, monitoring will focus on the ocean-atmosphere system in the tropical region of the equatorial Pacific in order to provide an early warning so that timely decisions may be taken with a view to mitigating any adverse effects of the phenomenon and/or taking advantage of whatever benefits that it may offer.

METEOROLOGICAL APPLICATIONS IN AFRICA: STATUS, PROBLEMS AND POSSIBLE SOLUTIONS*

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ABSTRACT

National Meteorological Services (NMSs) in Africa have a role to play in the economic development and well-being of their respective countries. To do this, they must establish, maintain and operate certain basic facilities. These facilities include meteorological observation networks, meteorological telecommunications systems and data processing systems. However, due to a lack of proper orientation or awareness of government authorities and users on the value of meteorology to economic development and the strained economic situation prevailing in many African countries, there has been a low level of implementation of the basic facilities in Africa. The communication facilities of METEOSAT offer the best solution to most of the problems facing NMSs in Africa today.

INTRODUCTION

Meteorology has developed beyond being just a service to aviation alone. It has an important role to play in the economic and social development of nations. In this regard, the functions of a meteorological service may be summarized as follows:

(a) provision of meteorological and climatological service to agriculture;

(b) provision of meteorological and climatological service to water resources development;

(c) provision of meteorological service to both civil and military aviation for the safety and economy of aircraft operations;

(d) provision of meteorological service to shipping for the safety and economy of ships;

(e) provision of meteorological service to tourism;

(f) provision of meteorological and climatological advice to the private sector including industry, commerce and public utilities;

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* This paper, which was presented at the United Nations Regional Conference on Space Technology for Sustainable Development in Africa, held in Dakar, Senegal, from 25-29 October 1993, does not necessarily reflect the views of the United Nations.

(g) provision of meteorological and climatological services for the conservation of nature;

(h) provision of meteorological and climatological advice for the improvement and preservation of the national environment for better human existence; and

(i) provision of meteorological and climatological services for the development of energy.

To be able to satisfactorily perform these functions, it is essential that a meteorological service organize and maintain a surface and upper-air meteorological observation network within its national borders. It must also establish and maintain an efficient telecommunications network for rapid collection and dissemination of meteorological information required for national and international use in accordance with procedures established by the World Meteorological Organisation (WMO) and the International Civil Aviation Organization (ICAO). In addition, it must establish and maintain a capability to process meteorological information and make forecasts for its customers. These are the systems that form the basic components of the WMO World Weather Watch (WWW) systems.

The implementation of the Aircraft-to-Satellite Data Relay (ASDAR) programme began in early 1991 when four commercial aircraft were fitted with the ASDAR system for reporting temperature, wind speed and direction, time, position and turbulence. An additional five aircraft were expected to be fitted by mid-1992, and the remaining four later in 1992, which would have completed the original implementation of thirteen units. Negotiations for the purchase of additional ASDAR systems were in progress.

CLIMAT AND CLIMAT TEMP REPORTING STATIONS

According to information provided by African Members of WMO, the network has 436 CLIMAT reporting stations and 64 CLIMAT TEMP reporting stations. The requirement is for up to ten CLIMAT stations per 250,000 km^2 which translates into a total of 1,200 stations. Clearly, this is not possible. Having 600 reporting stations, however, or five per 250,000 km^2 would be a reasonable target.

The WMO coordinated monitoring shows that only approximately 80 CLIMAT reports and 15 CLIMAT TEMP reports from Africa are received at Bracknell.

Space-Based Subsystems

The two main components of the space-based subsystems of the Global Observing System (polar-orbiting and geostationary) have continued to improve while providing standard services to WMO Members in Africa.

The polar-orbiting satellite NOAA-9, launched in December 1984, performed during

its two-year expected life and is now on standby status. NOAA-10, launched on 17 September 1987, is the prime morning spacecraft. On 9 November 1988 NOAA-11 replaced NOAA-9 for operational data as the afternoon satellite. On 6 June 1991, NOAA-12 was launched. The Russian Federation has continued the METEOR-2 series of polar-orbiting satellites composed of two to three satellites at an average altitude of about 900 km. On 24 October 1985, a new improved series of polar-orbiting satellites, METEOR-3 was launched. These satellites are flown on near circular orbits at an altitude of about 1200-1250 km. A further enhancement is expected to the METEOR-3 series so that it will be able to provide a direct broadcast similar to a high resolution picture transmission (HRPT). This enhancement is expected to be in place by the middle of the 1990s. The People's Republic of China also has in orbit two experimental polar-orbiting satellites, each providing data in a format compatible for any HRPT ground receiver.

Africa continues to be served by the METEOSAT geostationary satellites. Following three pre-operational satellites, the first operational satellite, METEOSAT-4, was launched in March 1989 and METEOSAT-5 was launched in March 1991. These provide a full service of high and low-resolution visible and infrared imagery as well as information on upper-winds based on cloud movement.

STATUS OF IMPLEMENTATION AND OPERATION OF WWW FACILITIES IN AFRICA

The Observation Network

A total of 721 surface stations and 139 upper-air stations were included in the total Regional Basic Synoptic Network (RBSN) for Africa. According to the latest statistics, the level of implementation of the network remains at about 76 per cent for surface stations and 47 per cent for upper-air stations. As may be seen from table 1, the implementation of the observing programmes ranges from 57 per cent at 2100 UTC to 87 per cent at 0600 and 1200 UTC for surface stations, and for radio stations from 36 per cent at 0000 to 61 per cent at 1200 UTC.

In considering these figures, two points should perhaps be emphasized: the network has evolved gradually on the basis of national programmes and plans rather than being designed on a regional scale with a specific spacing between stations in mind. To cover the land area of Africa which is roughly 35 million km^2, a total of roughly 620 stations would be required with spacing of 250 km. Clearly, this is not possible in the remote areas of the continent where the distance between stations may be 500 km or more, but, as the total of 721 stations in the RBSN is more than the total required, and 630 of these have actually been established, there is a concentration of stations in the more populated areas.

The second point is that the implementation figures referred to in the tables are based on information given by individual countries on the establishment of stations and the observing programmes. They are neither always updated promptly nor do they allow for temporary stoppages in operations. A true guide may be the result of the WMO coordinated annual

monitoring which shows that 29 per cent of the required surface reports and 20 per cent of the upper-air reports from Africa reaches centres on the GTS. This, however, does not distinguish between deficiencies in observing programmes and those in telecommunications. Furthermore, the monitoring period, which is normally 15 days, is a rather short time upon which to assess overall performance.

Other Networks, Including Sea Stations

The WMO coordinated monitoring has shown that on average, 58 SHIP reports from Africa reach centres on the GTS everyday.

Concerning the new systems for automated upper-air observations at sea and by aircraft, the Automated Shipboard Aerological Programme (ASAP) is now a completely operational component of the WWW with 13 ships equipped in the North Atlantic and 2 in the North Pacific. Full TEMP reports are received from these ships twice a day when they are at sea.

TABLE 1

SURFACE OBSERVATIONS

	00	03	06	09	12	15	18	21
Observations requested	721	721	721	721	721	721	721	721
Observations made	433	516	628	605	626	595	558	411
Implementation rate (%)	60	72	87	84	87	83	77	57
(global average)	(88)	(84)	(89)	(86)	(93)	(87)	(90)	84)

SURFACE STATIONS

Requested in RSBN	Making complete observation programme	Making obs. at least four main standard	Less than four obs. per day	Not yet established
721	388	40	33	89

UPPER-AIR OBSERVATIONS

	R/S		R/W	
	00	12	00	12
Requested in RSBN	99	99	139	139
Implemented	36	60	48	81
Percentage (%)	36	61	35	58
(Global average)	(80)	(81)	(77)	(81.6)

UPPER-AIR STATIONS

Requested		Complete obs. programme		One obs. per day		Not yet established	
R/S	R/W	R/S(2)	R/W(4)	R/S	R/W	R/S	R/W
99	139	31	44	34	39	34	56

The spare satellite METEOSAT-3 is now providing data on the Atlantic region from its position at 50°W. It provides image pre-processing and dissemination of time multiplexed digital image data from the central ground segment at Darmstadt, Germany, and WEFAX transmissions from the facilities at Lannion, France.

With the launch of the METEOSAT Operational Programme (MOP), an operational Meteorological Data Distribution (MDD) schedule began in mid-February 1992, having been performed on a pre-operational basis since early 1990. The system is comprised of two uplink stations, one in Bracknell, United Kingdom, and the other in Rome, Italy. A WMO evaluation programme has been conducted using user stations located in several national meteorological centres in Africa.

The Telecommunication Network

Table 2 summarizes the telecommunications situation in Africa as of January 1993. Further to that, there are plans to implement a major telecommunication loop linking the Regional Telecommunication Hubs (RTHs) in Algiers, Dakar, Niamey and Nairobi. These centres have already automated their telecommunication systems. A new automatic message switching system was installed at the Nairobi RTH and became operational in April 1993. The plan is to establish

the links on the loop to conform to Recommendation V.29 of CCITT using X.25 procedures and to have the loop implemented by 31 December 1993. Niamey, Dakar and Algiers are already linked and plans are at an advanced stage to link Nairobi to Niamey and Algiers to complete the loop. This plan includes the upgrading of the circuits between the loop and RTHs at Brazzaville and Lusaka.

At the national level, it is not possible to include a detailed analysis of the existing telecommunication facilities in each African country in a paper like this -- it would end up being a huge, voluminous document. In any case, the deficiencies of the national telecommunication networks in Africa are well documented and need not be repeated here. It is sufficient to say that in Africa, compared to other W) regions, high frequency (HF) techniques are used more than PTT services as a means for the collection of meteorological data from observation sites. The HF mode of communication suffers severe atmospheric interference which renders it highly inefficient and, moreover, the maintenance of HF systems is very expensive. The use of PTT services should, therefore, be encouraged.

TABLE 2

CIRCUITS

			Telecommunication means satellite/cable microwave		
G T S	Circuits called for in GTS plan	Implemented circuits	Telephone-type	Telegraphic	HF Radio
Region I	83	59	2	32	25

PRESENT STATE OF THE OPERATION OF RADIO BROADCASTS BY WMCS/RTHs
(January 1993)

WMO Regional Association	Radio teleprinter broadcasts		Radio-facsimile broadcasts	
	Centre	# of broadcasts	Centre	# of broadcasts
I (AFRICA)	Algiers	1	Cairo	1
	Brazzaville	1	Dakar	1
	Cairo	1	Nairobi	1
	Dakar	1		
	Kano	1		
	Nairobi	1		

LIST OF AUTOMATED CENTRES
(January 1993)

WMO Regional Association	RTHs	RSMCs/NMCs
I - AFRICA	Algiers Brazzaville Cairo Casablanca Dakar Nairobi Niamey Lusaka	Antananarivo/Ivato - Libreville Abidjan - Lomé Addis Ababa - Ndjamena Bamako - Nouakchott Banjul - Ougadougou Cotonu - St. Denis Douala - Tunis Gaborone

THE DATA PROCESSING SYSTEM

Regional Specialized Meteorological Centres (RSMCs) with geographic specialization

The RSMCs with geographic specialization in Africa are Algiers, Antananarivo, Cairo, Dakar, Lagos, Nairobi and Tunis/Casablanca. Some of these RSMCs are either not operational or do not have an adequate infrastructure necessary to perform their designated functions.

Considering the requirements of the region for such centres, the plan now is to have at least one RTH/RSMC in each of the five sub-regions of Africa. The following operational centres have been recommended for inclusion in the revised structure.

West Africa - RTH/RSMC Dakar
North Africa - RTH/RSMC Algiers
East Africa - RTH/RSMC Nairobi
Central Africa - RTH Brazzaville
Southern Africa - RTH Lusaka

Of the above centres, RSMC Algiers has an adequate computing infrastructure while RSMC Nairobi has a basic computing infrastructure which needs to be upgraded to bridge the gap in capabilities. This includes training of staff to better handle real-time data processing systems functions. RSMC Dakar lacks basic computing infrastructure and requires provision for the training of relevant staff and the implementation of minimum computing facilities necessary for the further upgrading and discharging of its RSMC functions.

RSMCs with activity specialization

The African Centre of Meteorological Applications to Development (ACMAD), situated in Niamey, Niger, has started an operational activities unit using short-period seconded staff from various African meteorological services. The unit issues weather forecast bulletins covering the African continent with a validity of 72 hours

The equipment available at ACMAD includes:

a) SUN Workstation - CPU 8MB, processor SPARC 25 mhz. This provides ACMAD with direct access to the meteorological data bank of Meteo-France in Toulouse through the use of the Public Switched Telecommunication Network (PSTN). NIGERPAC and TRANSPAC provide the necessary network access;

b) Microcomputer - VAX 3100 model 84 - CPU 16MB, disk 104 MB for use in the area of climatic applications;

c) Zenith Personal Computer (PC) - 386SX with a co-processor 387SX - CPU 2MB, disk 40MB, for use in animation of satellite imagery acquired by a METEOSAT Primary Data User Station (PDUS) and to prepare and edit weather bulletins; and

d) Meteorological Data Distribution (MDD) user station for reception of processed products from the more advanced centres.

In addition to the MDD service, ACMAD's telecommunications facilities include one standard telephone exchange unit, direct telephone lines and three telefax machines.

The Drought Monitoring Centres (DMCs) in Nairobi and Harare

In January 1989 the United Nations Development Programme (UNDP) and the World Meteorological Organization (WMO) began a project on "Drought Monitoring in Eastern and Southern Africa." The main goal of the project is to alleviate the negative impacts of drought and other related adverse weather conditions upon agricultural production and natural resources through improved application of meteorological data and products.

In order to achieve this goal, the following objectives were established:

a) establishment of a databank to facilitate the operational capabilities of the centres;

b) development of methodologies in drought monitoring, seasonal weather forecasting and applied agrometeorology and hydrometeorology at the sub-regional level;

c) development of methods to disseminate products in a suitable format to be used by national authorities and farmers;

d) training of specialized personnel in relevant areas to enhance the capabilities of participating countries to monitor drought and give seasonal weather forecasts; and

e) establishment of mechanisms for the transfer of technology within the sub-region.

The DMCs have continued to monitor drought on a timely basis and give early warning for the formulation of appropriate strategies to combat its adverse effects. In other words, the DMCs have sustained the sub-regional climate diagnostic centres status so that all information relating to drought and weather patterns is readily available to interested users within and outside the eastern and southern African sub-region.

Products that are prepared and disseminated by the DMCs are:

a) Dekadal climatological summary and drought severity;

b) Dekadal agrometeorological conditions and impacts;

c) Dekadal synoptic review and weather outlook for the subregion;

d) monthly and quarterly climatological summary and drought severity conditions for the sub-region;

e) dominant synoptic systems and three month weather forecasts for the sub-region;

f) agrometeorological conditions and impacts in the subregion; and

g) Dekadal, monthly and quarterly actual meteorological data for the sub-region.

The DMCs' databank is being enhanced by the acquisition of data which had hitherto not been provided and by updating existing data with more recent information. This is to ensure that the DMCs can provide specialized information upon request from interested parties. The DMCs have endeavoured to train specialized personnel through attachments, workshops and courses.

<u>The AGRHYMET Centre in Niamey, Niger</u>

The Centre falls under the Permanent Inter-State Committee on Drought Control in the Sahel (CILSS). CILSS was established in 1973 as an expression of the desire to control drought by the nine countries of West Africa most severely affected by drought: Burkina Faso, Cape Verde, Chad, Gambia, Guinea Bissau, Mali, Mauritania, Niger and Senegal.

This Centre, which was established within the AGRHYMET programme and implemented by WMO, has the following objectives:

a) to develop and put into operation observation methodologies for collecting the data

required to monitor weather, crops, grasslands and surface water;

b) to store data in the Centre's databank, analyze them and make them available to national centres and other interested users;

c) to contribute to putting into operation early warning systems at the national, regional and global levels by providing meteorological, agrometeorological and hydrological information and forecasts;

d) to contribute to national and regional efforts to increase agricultural production through the introduction of agrometeorological and hydrological information into existing production methods; and

e) to train specialists, in order to strengthen the national services and the centre.

Presently, the Centre is composed of training, operational and technical services departments, a hydrology office as well as administrative and financial services.

The current activities of the Centre include training and the reception and utilization of satellite data. The products currently received from NOAA images are vegetation index (NDVI) maps which are released at ten-day intervals. These cover the entire CILSS region and can extend to northern Africa and eastward to the Nile Valley. The NDVI maps are distributed by mail to the national components of the AGRHYMET programme.

The Tropical Cyclone Centre in Saint Denis, Reunion

The Tropical Cyclone Committee of the African Regional Association recommended that a Tropical Cyclone Advisory Centre be established in Reunion, France. The main aim of the Centre is to carry out specialized activities in the southwest Indian Ocean.

The responsibilities of the Centre are as follows:

a) establishment of communication links with RTH Nairobi and other sub-regional centres;

b) establishment of HRPT reception facilities;

c) preparation of advisory reports for the southwest Indian Ocean region; and

d) dissemination of these advisories to all NMCs.

THE PROBLEMS

The WWW system in Africa: the plan vs. implementation

Implementation of the Global Observing System (GOS) in Africa can be summarized as follows:

a) Not all stations shown in the regional plan have been established. Monitoring results show that the level of implementation is only 76 per cent for surface stations and 47 per cent for upper-air stations;

b) Those stations that have been implemented are neither fully operational nor functioning continuously, particularly during night-time observations. The availability of SYNOP data within six hours of observation time at centres on the GTS, from the implemented stations ranges from 40 per cent at 0000 UTC to 55 per cent at 0600 UTC. Some of the missing data can be attributed to telecommunication problems; and

c) The quality of the observational data, in quite a number of cases, is unreliable.

The Global Telecommunication System (GTS)

Regarding the implementation of the GTS in Africa, the following conclusions can be safely drawn:

a) Not all planned links, comprising the national telecommunication networks, have been implemented. Reports on implementation indicate that the level of implementation for the collection of data ranges from 45 per cent for 2100 UTC to 74 per cent for 1200 UTC. The links already implemented also lack efficiency and continuity; and

b) The GTS plan calls for reliable regional and main regional circuits, main telecommunication network circuits and inter-regional circuits. To date, not all planned links have been established and reports on implementation indicate that the level of implementation for regional circuits is approximately 70 per cent. What is worse is that the implemented circuits are mainly HF radio links and are unreliable. As a result, the observational data available on a daily basis is, on average, only 49 per cent of what was expected.

While it is difficult to assess the functioning of the Global Data Processing System (GDPS) because no monitoring results are available, it can be said that it has not performed to the required level of expectations. This is true because NMCs in Africa resort to acquiring observational data from various centres to prepare their own processed information to fill the gap created by the Regional Meteorological Centres.

Reasons for the deficiencies in the implementation of the WWW in Africa

Two basic problems exist in African countries which are the main causes of the specific technical problems leading to a low level of implementation of the key WWW facilities in these countries. One reason is the lack of proper orientation or awareness of government authorities (including some directors of national meteorological services) and users at large, on the value of meteorology to economic development. A second reason is that even if African policy makers recognize the importance of meteorology, the strained economic situation prevailing in most African countries prevents governments from giving the necessary support to meteorological services.

Because of this, the following specific problems arise. Because of the lack of sufficient observational equipment and inadequate manpower to run the stations, the planned synoptic network may not be fully implemented. The operation of stations already implemented may be suspended or interrupted due to a lack of replacement equipment, spare parts, consumables or trained manpower to maintain faulty equipment. Maintaining the level of operation of existing upper-air stations is difficult because of the increasing costs of operating these stations and implementing synoptic stations in sparsely populated and inaccessible areas is also difficult.

Additionally, the quality of observations is not maintained to the required standard or is degraded because of the lack of organized instrument calibration and testing centres in the country or poor management of the stations in terms of delayed responses to requests from the stations or a lack of inspection and supervision programmes.

Adequate telecommunication facilities are not made available for national data collection and for regional or global data exchange. The lack of trained technicians and spare parts are the primary reasons for the poor performance of telecommunication facilities. Replacement of outmoded and aged equipment is not given enough attention because of lack of resources.

Most RTHs and RMCs in Africa do not perform their responsibilities satisfactorily because of the minimum support given to them by national governments. This is a result of authorities not being made fully aware of the international obligations in this regard or because of technical incompetence of the centres themselves.

POSSIBLE SOLUTIONS

After a careful analysis of monitoring results for Africa, reports of individual countries and of experts visiting the various countries, it is quite obvious that substantial amounts of observational meteorological data exist at stations or national centres. Consequently, there has evolved a consensus that the major problems in Africa are the slow and incomplete national collection of meteorological data by a number of the NMCs in the region and their onward transmission to the respective RTHs. Simply, the capabilities of the communications are inadequate to exchange these data on the GTS.

An Operational WWW Systems Evaluation for Africa (OWSE-AF), concentrating on the improvement of meteorological telecommunications in Africa, has recently been conducted. Phase I was designed to solve the problem of the availability of African data on the GTS by using the Data Collection System (DCS) and Data Collection Platform Retransmission System of METEOSAT. Phase II of OWSE-AF was to provide a solution to the problem of reception of processed information at NMCs in Africa through the use of METEOSAT's MDD function. The main aim of the OWSE-AF was to determine the impact on the GTS in Africa of using METEOSAT satellite communications for the collection of observational data and exchange of both data and products.

No meteorological observations have been received in several years from many African countries, notably Ghana, Nigeria, Sudan and Zaire. After the installation of the DCS and DRS as part of OWSE-AF Phase I, and before the early equipment failures, the availability of observational data from these countries at the NMCs and centres within Africa increased from near zero to a regular flow. The data was received clearly and the few corrupt messages that went through the system were due to operator mistakes at the originating site. Phase I of OWSE-AF showed that the use of DCP/DRS had a significant impact on the availability of observational data at NMCs in Africa.

According to reports, those NMCs with MDD systems received processed products prepared in Offenbach, Germany, Toulouse, France, Bracknell, United Kingdom, and the DMCs in Nairobi, Kenya and Harare, Zimbabwe. They also received some alphanumeric data through the uplink station in Rome, Italy. Phase II of OWSE-AF showed that the use of MDD had a significant impact on the reception of processed data at the NMCs in Africa and on data from the more advanced centres on the GTS.

With the availability of the DCP/DRS communication, it is possible and quite feasible to enhance the observation network in Africa using automatic stations. Manned observation stations are too expensive and difficult to operate in remote and sparsely populated areas.

Even with the introduction of new technologies in Africa, training of operators, engineers/technicians and all other staff involved is very essential. Some levels of training may best be done in the factory.

THE CASE FOR BASIC SPACE SCIENCE IN AFRICA*

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In the context of sustainable development, the case for space science is to be found implicitly in the action programmes clearly and carefully mapped out in the Agenda 21 documents of the United Nations Conference on Environment and Development, also known as the Earth Summit (United Nations, 1992). Many of the programmes involve the observation and monitoring of various aspects of the Earth's resources and the assessment and evaluation of the information obtained to support more meaningful decisions and policies. In a critical examination of the means by which the objectives of the programmes are to be achieved, scientific and technological capacity is prominently featured. Many aspects of the programmes also require more efficient ways of using our natural resources, in the sense of more efficient uses of energy and applying more environmentally friendly technologies. Thus, in seeking a better understanding of the Earth in order to appreciate the effects of human actions on Earth system processes, in monitoring the changes that occur with time and in the search for more environmentally sustainable ways of using and managing the Earth's resources, the need for scientific and technological capacity is obvious.

One of the input documents contributed by the International Council for Scientific Unions (ICSU) to the Earth Summit, An Agenda of Science for Environment and Development into the 21st Century (ASCEND 21, 1992), addressed the contributions which science could and should make to the analysis and solution of problems of development and environment. This document is the result of an international conference of scientists, which took place in November 1991. The objectives of the ASCEND 21 Conference were "to bring together the understanding and judgement of the world scientific community (encompassing natural, social, engineering and health scientists), on the issues of highest priority for the future of the environment and development, so as to define the agenda of science in these areas for the next 10 to 20 years." (Dooge & Marton-Lefevre, 1992) The document which resulted from the deliberations is seen as a basis for future action by the world's scientific community. In the chapter on Capacity Building, it was stated (Bekoe and Prage, 1992, p.255) that for successful implementation of the UNCED decisions, as then anticipated, radical change towards sustainable development practices and capacity building will be necessary in all countries but much more so in the developing countries, and even more so in Africa. Capacity building in this context is meant to include the training and education of scientists, engineers, health scientists and social scientists, the establishment and strengthening of appropriate institutions in which these persons work and interact, and building the infrastructure, encompassing policy framework and management, which will enable them to achieve their stated objectives. In many countries, including most of Africa,

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* This paper, which was presented at the United Nations Regional Conference on Space Technology for Sustainable Development in Africa, held in Dakar, Senegal, from 25-29 October, 1993, does not necessarily reflect the views of the United Nations.

there are gaps in training, in the network of institutions, and in the infrastructure, including management structures and policy-making bodies. There is also a need to strengthen and reorient all these components to work more effectively towards the stated goals.

One of the gaps in human resource development worldwide is in the area of taxonomy. It used to be of considerable interest to scientists all over the world. In recent times if has been less attractive to young scientists, and even less so to scientists in the developing countries. The result of this shortfall is that names have been given to only about 1.4 million of the estimated 10 million species of organisms (Arroyo, Raven and Sarukhan, 1992 p.205). The requisite manpower needs to be greatly increased, particularly in developing countries, partly to enable their own biodiversity to be used for their national development.

There are also other gaps in capacity which constrain the sustainable use of natural resources for national development. One such area is that of space science in which the participation of African scientists is at present minimal. Yet there are fields of application which could greatly benefit African countries, particularly for monitoring, management and preservation of their natural resources. These applications involve the use of technologies developed for space exploration and space science. Although such technologies are available for purchase, for their effective use, they need to be understood; they often need to be adapted; they need to be developed and constantly improved; and they need to be researched in order to evolve new technologies and better understanding. Space science means many different things to different people. To some it means exploring the moon and the other planets. To others it means the exploration of the Earth from space, more commonly referred to as remote sensing. Both of these make use of space technology. Other meanings relate to the study of science in space, which is an extension of studies of scientific phenomena in the extraordinary environment of space -- its gravity-free and vacuum-like condition -- or the scientific study of space itself.

A case for space science in Africa can be made in terms of current and future needs and technology development for sustainable use of Africa's natural resources. In every area of resource use, progress towards sustainability will depend on observation and continuous monitoring of the resources, an understanding of the driving forces which lead to changes in these resources (including human pressures) and responsible responses to ensure that future patterns of resource use are "environmentally tolerable, economically efficient and socially acceptable" (T. O'Riordan, 1992, p.223). Observation and monitoring require trained persons, efficient measuring technologies and adequate equipment for the recording of data. Understanding of the driving forces requires a minimum level of analysis and multidisciplinarity. And responsible responses require, among other things, a range of production technologies from which appropriate choices can be made. As already noted, capacity building needs particular attention in Africa. Africa lags behind the developed world in the number of scientists and engineers by at least a factor of 10. To partly make up for this gap, efficient methods of observation, analysis and production must be sought. It is suggested that it is in some of the fast developing sciences and the newer technologies such as those of space science that some bridge-building is possible.

For the present, an obvious case exists for the strengthening of Africa's capability in

remote sensing. Among the developing countries, Asia and Latin America are far ahead of Africa. There are regular courses in universities and other institutions devoted to the study of its principles and applications. Occasionally, small windows of opportunity are opened to African scientists to undergo training in such institutions. For example, this year ICSU's Committee on Science and Technology in Developing Countries (COSTED) has highlighted this area by organizing two activities. The first is a Training Workshop in Madras, India, on Applications of Remote Sensing for Developing Countries. The second is a Workshop in Hyderabad, India, on Application of Satellite Remote Sensing for Identifying and Forecasting Potential Fishing Zones in Developing Countries. Remote sensing has a wide range of applications. The second workshop cited above is an example of the use of remote sensing for the observation, planning and utilization of living and non-living marine resources. Information on terrestrial resources, from which most of our food, fuel, fibre and shelter are derived, is similarly obtainable through remote sensing together with in situ measurements. Observation and study of the dynamics of the ocean margins and land-sea interface can also be pursued in this manner. Finally, remote sensing provides opportunities for observations of hydrologic and bio-geochemical phenomena. Much work however remains to be done in the calibration and interpretation of images. For observations such as soil moisture or soil carbon which are measurable with great difficulty and low precision even at discrete points, expected improvements in the ability to characterize soil moisture states over large areas will be a major contribution to the understanding and modeling of the hydrologic and bio-geochemical cycles.

It should be noted that no country can protect and develop its environment in isolation. There is a need for awareness of regional and global trends in environmental change. Environmental degradation due to natural causes (such as drought, pests, etc.), from human activities (such as acid rain, desert encroachment, intolerable toxic and hazardous waste management practices. etc.) do not often originate within the borders of a country. In particular, attention must be paid to activities that have global effects: ozone layer depletion and global warming. In other words, information on neighbouring as well as distant countries is required. Hence, there is a tremendous need for international cooperation in data collection, management and analysis systems and in developing environmental models that are crucial to the understanding and protection of the environment and which ensure the effective management of natural resources nationally and globally.

As part of the implementation process for Agenda 21, a number of global observing systems are being established: a Global Climate Observing System (GCOS), a Global Ocean Observing System (GOOS), and a Global Terrestrial Observing System (GTOS). African countries should prepare themselves to participate in the work of these observation and monitoring systems.

There are a few institutions in Sub-Saharan Africa in which work on remotely-sensed data is undertaken, such as the Nairobi-based Regional Centre for Services in Surveying, Mapping and Remote Sensing (RECTAS). There are also national institutions in Nigeria, Kenya and a few other countries. The existing regional and national centres provide some training and invariably a heavy load of service. For deep involvement in research and improvement in technology, basic

education and training must be more widely available and accessible for younger scientists. I am particularly pleased to note the systematic developments in this respect in Nigeria with the National Agency for Science and Engineering Infrastructure (NASENI) taking important initiatives and playing a much-needed coordinating and advisory role. The ad hoc establishment of a number of isolated institutions for basic space science and technology and their applications will hopefully come to an end and all the existing and future institutions placed within a loyal framework.

Agenda 21, as stated in its preamble calls for "global partnership for sustainable development." It is a dynamic programme and process, an action plan which is the beginning of the new global partnership. While its successful implementation is primarily the responsibility of governments, bearing in mind that they are the overall planners and managers of economic and social development, the support of international cooperation, nongovernmental organizations and the broadest public participation is necessary. Section II of the plan deals with "Conservation and Management of Resources for Development" and gives comprehensive coverage to the areas that require attention:

- protection of the atmosphere
- management of land resources
- combating desertification and drought
- sustainable agriculture and rural development
- management of biological diversity
- the oceans, coastal areas and the protection, rational use and development of their living resources
- quality and supply of freshwater resources
- management of toxic chemicals and hazardous wastes

These are the areas which require specific scientific and technological inputs as identified within each programme: observation and monitoring; analysis and modelling; new, environmentally-friendly technologies; greater efficiency in the use of resources; human resource development in terms of specializations such as remote sensing, mapping and statistical modelling.

In Section III, "Strengthening the Role of Major Groups", a special chapter is devoted to the scientific and technical community. And finally, in Section IV, on the "Means of Implementation," in the chapter on Science for Sustainable Development, Agenda 21 "focuses on the role and the use of the sciences in supporting prudent management of the environment and development for the daily survival and future development of humanity.....One role of the sciences should be to provide information to better enable formulation and selection of environment and development policies in the decision-making process. In order to fulfill this requirement, it will be essential to enhance scientific understanding, improve long-term scientific assessments, strengthen scientific capacities in all countries and ensure that the sciences are responsive to emerging needs." It is in this regard that Africa must assess its scientific and technological capacity and take appropriate action on the critical gaps in that capacity.

For purposes of discussing the science of space and science in space, it is necessary to give more meaning to the term space. It may be defined as "that portion of our outer environment, above the aerodynamically navigable atmosphere, which can be directly and in situ probed by humans and human-made devices." (Roederer, 1990, p.48) It can be studied with ground-based instrumentation and from Earth-bound platforms such as aircraft and balloons. It is not empty and consists of plasma-hot gas in a state of partial or total ionization. Space plasma physics studies the ionized gas envelopes of the Sun, the planets and other solar system bodies (eg. the "tails" of comets). Such studies contribute to the qualitative understanding of the dynamic behaviour of stars, galaxies and other distant objects, and are important for the understanding of the behaviour of laboratory plasmas, such as those used in controlled thermonuclear fusion devices, the generation of solar disturbances such as solar flares and sunspots, and their effects on the terrestrial environment. Aeronomy, the other aspect of space physics, studies the interaction between the ionized and neutral components of the upper atmosphere, electromagnetic radiation and energetic particles. This contributes to a better understanding of the propagation of solar disturbance effects into the deeper layers of the atmosphere. Together, these two aspects of space physics provide fundamental scientific information on the space between the Earth's atmosphere and the Sun, which is required for the prediction of "weather and climate in space" to guide explorations into and communications through this space. These studies are coordinated by ICSU's Scientific Committee on Solar-Terrestrial Physics (SCOSTEP).

With regard to the study of science in space two examples will suffice. The near absence of gravity enables the study of processes such as crystal growth or the behaviour of an individual biological cell or cell colony or human physiological processes without the "disturbing" influence of gravity that exists on Earth. Processes studied under the near vacuum conditions of space include solid state physics and the survival of viruses.

It is understandable to be skeptical about the benefit of such studies to a developing country. But it is instructive to note that even in developed countries only a small number of groups are actually involved in the building and launching of space instrumentation. They operate through collaborative mechanisms in which basic science and technology converge, with benefits to all the viable scientific and technological teams.

A vital aspect of space science and space technology is effective and reliable communication. Special needs are being identified and several special technologies are being developed to meet these needs: data transmission, data analysis, special communication facilities using computers, satellites and radio.

Many new technologies developed in space science programmes are finding applications in ordinary life -- the so-called spin-offs. These include more efficient solar energy devices and miniaturization of a variety of scientific equipment. They should provide the choice of new technologies which will be required to make better observations and more efficient production processes. Participation in such programmes will also help Africa develop the capacities for analysis and synthesis of large amounts of data which scientific support for sustainable

development demands. Many of these spin-offs are being adapted for communications between scientists, scientific communication in general as well as for educational, health and other social purposes which should promote the greatest possible participation of all humanity.

There will continue to be problems in Africa -- problems of capacity building, problems of having sufficient numbers of trained personnel, problems of equipment purchase and maintenance, of inadequate operating costs and infrastructure, and of brain drain. But at least plans and strategies should be available so that implementation of Africa's real entry into the age of space science and technology and their application can take off with solid foundations.

THE FRENCH GOVERNMENT TECHNICAL COOPERATION PROGRAMME WITH RECTAS FOR THE DEVELOPMENT OF REMOTE SENSING IN THE SUB-REGION AND ITS IMPACT ON BASIC SPACE SCIENCES*

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INTRODUCTION

In the past five years the development of remote sensing at the Regional Centre for Training in Aerospace Survey (RECTAS) has been accelerated with technical assistance from the Government of France through its Ministry of Foreign Affairs and Technical Cooperation. The main idea behind this cooperation is that enhancing the capability of RECTAS would directly benefit the sub-region's development of manpower for remote sensing applications.

This paper outlines what has been achieved since 1988. In the last five years, nearly all the Centre's academic and research staff have received some training in remote sensing. The range of digital processing equipment has been widened, and the Centre's staff has been augmented with resident French experts. These facilities have facilitated revision of the curricula for three levels of training: technician, the technologist and postgraduate. The subject matter of the curricula is also shifting in emphasis from the traditional photo-interpretation to computer uses for data conversion from digital to analogue and vice-versa. To understand space images there are courses in aspects of basic space science related to energy propagation through space and spectral reflectance of objects within the electro-magnetic spectrum. In addition, the Centre has realized the need to start technical training in laboratory equipment maintenance in order to train skilled technicians for hardware and software maintenance. The Centre has already made some progress with the assistance so far rendered by the cooperative arrangement with France. The objective of developing RECTAS for shared-use by scientists, engineers and technologists in the sub-region, is already being achieved within the present level of the Centre's capabilities, due to the cooperation with France.

THE ROLE OF REMOTE SENSING

There are two major elements of remote sensing.1/ They are: a) aspects of data collection which concern the design of sensors, and the imaging performed by the sensor; and b) aspects of data analysis, that is the use of digital and analogue systems for image data conversion.

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The role remote sensing plays in space science and technology is its capability to produce images from the spatial and spectral measurements of material objects that have been sensed. The daily weather forecasts on CNN are possible because of the data supplied from the METEOSAT geostationary satellite and its three sister satellites located around the globe.2/

The Landsat Thematic Mapper (TM) has seven bands, six of which have 30m spatial resolution and the SPOT P and XS systems have spatial resolutions of 10m and 30m, respectively. These satellite systems make Earth surface cartography and environmental surveillance very possible and it is clear that the spatial resolution capabilities of space photography and scanner systems will improve in the future, thus allowing even better space cartography of the Earth's terrain and the associated environment. By the year 2000 improved spatial and spectral resolution will make it possible for humanity to collect information about the Earth and the environment which was never before available.

Remote sensing started with aerial photography and photo interpretation with analogue instruments. Now it has advanced as an art of computer-based numerical data processing of multispectral imagery. This art and technique will, as space technology improves, not be limited only to the Earth's terrain and atmosphere. Nor will the imaging of the Earth's terrain be possible in only a few spectral windows. Improvements in multispectral sensing will make it possible to see imageries in several spectral channels ranging from X-rays to the deep infrared and microwave regions of the electromagnetic spectrum.

The more varied the spectral channels, the greater the revelation of visibly hidden information will be, which computer-based processors will manipulate and turn into imagery for the human eye to see. It is therefore the art and the techniques of remote sensing that will convey the imagery from space observations to the ordinary public so they too can see what lies hidden not only in the deep space but also around us within our the Earth's environment.

Education in space science is therefore not complete without education and training in remote sensing. Both have to go hand-in-hand. The former creates the technology for observation, the latter brings the recorded observations into the open to enable the public to see what is normally out of their reach.

REMOTE SENSING APPLICATIONS IN AFRICA

Africa utilizes remote sensing technology less than any other continent.3/ What technology that it does utilize generally comes from abroad and is used primarily for data analysis. Endogenous African data analysis capabilities are limited.

There are, however, some major on-going developments that may convince African countries to increase efforts to create endogenous capabilities in remote sensing technology. These developments include the following:

- improvements in the resolution of remotely-sensed satellite imagery and their applicability to cartography and environmental surveillance;

- improvements in PC-technology with remarkable results including desk-top and briefcase image processing and map publishing; and

- the increasing requirement of some funding agencies that an Environmental Impact Assessment be conducted prior to provision of assistance funds and the indispensability of remote sensing techniques for conducting such assessments.

It is no surprise that most of the African countries which attended the Eighth United Nations Cartographic Conference for Africa reported on efforts being made by these countries to establish national remote sensing centres.4/

Remote sensing is no longer simply a technique but now constitutes a scientific discipline. As a discipline its development is consistent with the normal pyramid structure of manpower utilization. The base and middle sections of the pyramid consists of trained and skilled technicians and technologists, while the narrow apex is occupied by very few highly skilled professionals or engineers.

Admittedly, remote sensing is a high-tech, and equally a high-cost enterprise. Its development requires the backing of a scientific and technological culture. Because this culture is yet to be rooted in many African societies, the equipment and the expertise for the management of remote sensing activities will necessarily come from those countries advanced in space and computer technology.

The prospects for indigenous development looks even far more gloomy when it is viewed from the angle of funding, because in many African countries budgetary constraints threaten the political goodwill that exists for development of a remote sensing infrastructure. In many countries national attention is focused more on simple survival strategies.

Until the global recession ends, many African countries will be unable to balance their trade accounts with the industrial countries and most remote sensing assistance will continue to come from the originators of the technology. It is debatable, however, whether this is a wise path for African countries to pursue, though survival strategies often compel countries to choose this alternative.

One acknowledged method for overcoming these funding constraints is for poor countries to pull together and jointly utilize a few remote sensing centres in order to spread the high cost of their high-tech equipment among many countries.

This paper also agrees with United Nations resolutions that say developing countries should be made partners in space science development.

The cooperative project between RECTAS and France subtly reflects these issues.

THE FRENCH COOPERATION PROTOCOL AGREEMENT

Between 1985 and 1987, an increasing number of Nigerian institutions requested technical assistance in remote sensing from the cultural service of the French Embassy in Lagos. After an expert mission to many institutions in Nigeria, RECTAS was chosen to be

the focal point of the cooperative arrangement because of its international and regional character and because it is a specialized training centre for aerospace surveying.

It was expected that the Centre would be accessible to many national institutions in the host country, and, because of its bi-lingual character, to as many other African countries as possible.

The goal of the Protocol Agreement signed in 1988 was to facilitate remote sensing development by: a) training lecturers and instructors; b) providing training support, mostly through the secondment of experts; c) equipping laboratories and d) the periodic organization of technical and educational workshops.

France is a major world space power which came to the forefront of space technology in 1986 when it successfully placed the SPOT satellite into orbit. The satellite provide images of the Earth's surface with 10m and 20m resolution. Software development for image processing had also been advanced by some French scientific institutions such as CNES, IGN, and BRGM.

Among the French institutions that specialize in remote sensing the Group for the Development of Aerospace Remote Sensing (GDTA), which was formed by CNES, IGN, BRGM, BDPA and IFP, provides assistance to the regional remote sensing centres in Africa (Nairobi, Ouagadougou), and in Asia (AIT Bangkok).

RECTAS negotiated the cooperative agreement with France so it would be capable of complementing the efforts of the other existing regional institutions in Africa in serving the entire continent. Its bilingual character and its traditional field of photogrammetry make the Centre very much well-suited for the mission.

ELEMENTS OF THE FRENCH GOVERNMENT TECHNICAL COOPERATION PROGRAMME

The cooperative arrangement was designed to provide support for the Centre's remote sensing activities. Elements of the arrangement include:

1) assistance in the training of new and existing RECTAS lecturers and instructors to improve or/and reinforce their ability to provide high-level training adapted to modern technology;

2) Provision of the necessary support to RECTAS for its remote sensing training programmes and other activities to ensure that the institution can meet the requirements of African countries for manpower development;

3) Provision of equipment to RECTAS's remote sensing laboratories to make it possible for professionals to take advantage of digital satellite images for training, research and development projects;

4) Secondment of a Resident Expert to the Centre throughout the period of the project;

5) Tutoring of selected remote sensing trainees at RECTAS and participation in seminars and workshop organiszed by RECTAS to allow a greater number of African nationals to benefit from the Centre's programmes;

6) Encouragement of RECTAS staff in the development of high quality training materials;

7) Training of an African specialist in computer science to enable him/her to provide first level maintenance services within RECTAS and to extend such services to analogous institutions in Nigeria and other RECTAS member states;

8) Provision to RECTAS of micro-computers for image processing and a Geographic Information System, together with relevant software to enable RECTAS to have a well-equipped laboratory for its remote sensing activities;

9) Provision of other equipment and software required for word processing and the establishment of a computerized management system relevant to computer-based space data management;

10) Support for the above activities through active advisory services and annual technical missions which help RECTAS to properly maintain all equipment and software acquired for achieving the objectives;

11) Training of RECTAS's senior administrative and accounting staff in modern management and accounting skills, not only for the improvement of RECTAS but also to allow RECTAS to assist other institutions in these areas; and

12) Development of RECTAS's bi-lingual capacity in French and English to allow the institution to provide assistance to other regional institutions in both anglophone and francophone Africa.

IMPLICATIONS

The cooperative project commenced with the arrival of two French remote sensing hardware and software management experts. A number of satellite images in CCTs arrived and the existing three PCs for word, numerical and image data processing were linked with a more powerful workstation, a HYUNDAI HWS-S310, which has both image processing stations tied together in a network, as well as the SYNERGIS version of GIS.

Two additional COMPAQ-DESK PRO-386-20MB PCs, with printers, were added to the existing ones for common computer applications in order to leave the image processing unit free. In addition, three office-type desk-top computer units were installed for use for secretarial and accounting services. Peripherals supplied for the printing of output images include a TEKTRONIX-4693-DX for superior quality printing in A4 format, a HEWLETT-PACKARD-HP-PAINT-JET-XS which is used primarily for teaching purposes because its produces lower quality print-outs in A4 and A3 formats, and a TEKTRONIX-4696 (provided earlier by UNDP) for production of long (several meters) material in fairly acceptable quality. Also connected to the workstation for secretarial and accounting (as well

as training purposes) are three graphic printers: a HEWLETT-PACKARD Laserjet III, an EPSON-LQ-1050, and an EPSON FX-1050. Also of interest, several Magellan 3000 Pro model hand-held Global Positioning Systems (GPS) have been supplied for quick geographical location during field work.

In conjunction with another assistance project from the EEC, the Remote Sensing Unit now shares a cluster of eight PCs with the Photogrammetry Unit. Four of these are destined for the ILWIS software system configured at ITC and the remaining four will be adopted for use with analogue photogrammetric plotting instruments for computations. A more modern analytical plotter, the TRASTER T5, has also been delivered to RECTAS under the EEC project. This instrument takes both aerial and space imageries.

Recently, SYNERGIS software was installed on the SUN workstation. The other peripherals added to the network so far include:

- an Ao format digitizing table for cartographic work;
- a magnetic tape driver (YPHER-9000 Series, 6250/1600 bpi) which makes it possible to read and copy all common types of CCTs for image data acquisition or for saving important image files;
- an ARCHIEVE streamer (21505 model) where large (150 MB) files are saved;
- a magnetic-optic disk drive (RICOH-R-g200-E2) which makes it possible to save large files on removable disks of 2 x 300 MB; and
- a SONY CD-ROM optic disk drive, which makes it possible to read satellite imagery recorded under the new standard, which is more economical than CCTs.

Other items provided include a project car and a photocopier, to name only few, which have created the leverage for take off.

ACHIEVEMENTS

That the cooperative project has achieved such remarkable results can be seen from the current capabilities of the Centre. Its remote sensing curricula have been revised and the Centre can now afford to provide vital technical assistance to other remote sensing laboratories both within and outside Nigeria, in the training and in the uses of software for image processing.

The Centre is also beginning to undertake consultancy projects on image processing and interpretation. There are annual seminars at RECTAS, co-sponsored by CNES-GDTA, and these are mostly on new trends in remote sensing and space cartography.

CURRICULA DEVELOPMENT

The Centre's expansion of its equipment has enabled it to put in place revised training programmes for:

Technician - 18 month diploma course
Technologist - 18 month diploma course
Post-graduate - 12 month diploma course

The structures of the training programmes are common:

First Semester	-	Theoretical Knowledge and Skills
Second Semester	-	Knowledge and Practice of Remote Sensing
Third Semester	-	Application and Individualized Projects

The new features of the curricula are its emphasis on aspects of basic science in order to improve the background of the trainees for effective use of the equipment and also for better understanding of the numerical, and spectral character of the multispectral data they handle in the image processing.

The overall objective is, however, to have a trainee who has acquired the manipulative skills needed for effective exploitation of the hardware and software systems used for image processing. These technicians and technologists are expected to fit into the organizational structure of a remote sensing laboratory. The long training programme is meant to create a highly operational technical class.

TECHNICAL ASSISTANCE TO OTHER LABORATORIES

Three such laboratories were those of the National Water Resources Research Institute (NWRRI) at Kaduna, the Centre National de Télédetection du Benin (CENATEL), and Commission du Bassin du Lac Tchad.

RECTAS offered technical help to the former two to resuscitate their malfunctioning hardware and software systems. The success led to arrangements for a linkage agreement in order to utilize the maintenance capabilities of the Centre. The third lab requested special customized training for a staff member in order to enable him to operate a workstation the Commission had acquired. All three contacts had a common result -- sustainable cooperation. Obviously it is this achievement which seems to strongly justify the RECTAS-French Government cooperation project. The remarkable aspect of it is that the problems brought by the clients were solved entirely with the indigenous manpower which the training at GDTA in France had helped develop.

There has been one very interesting consultancy project which RECTAS participated in, which supported the assertion, noted above, that environmental impact assessments are becoming a condition for obtaining external funding. RECTAS was called upon to assist the National Electric Power Authority (NEPA) utilize remote sensing techniques to define and characterize a 250km corridor for the construction of a high tension line from Enugu to Yandev. This study was to be part of a proposal to be present for funding by the World Bank. The execution of the remote sensing element of the project was judged highly successful.

The last, but by no means the final activity, is the European Agency-supplied TM and MSS data for research. RECTAS has incorporated the data into its training project with the results that the trainees are working on a mixture of SPOT and Landsat TM of different dates for change detection.

RECTAS is also offering some help to the Forest Research Institute of Nigeria so the institute will be able to use its own consignment of imageries received from the ESA.

The active role played by RECTAS in the annual conference of the Nigerian Remote Sensing Society has been well acknowledged by its planning committees.

RECTAS itself is planning to launch a journal that will provide a forum for remote sensing practitioners to publish the results of their projects, and there are also plans to hold an annual seminar on new developments in remote sensing. All this is meant to create the awareness necessary to build a base of remote sensing technicians so that imagery coming from space systems can be effectively utilized.

CONCLUSIONS

RECTAS does not expect to compete with national institutions. It's goal is to complement them. It owes obligations to the host country in particular, and the Member States in general, to assist them in the harmonious development of their manpower. Its infrastructure and facilities exist for cooperative work for the advancement of space technology for mapping in Africa.

No one country can do it alone, the idea and existence of European Space Agency is a clear indication of the need for continental cooperation in order to reduce costs, minimize duplication of efforts and create interdependence for the continent to start the "warming up" process so it can catch up with the others regions already well immersed in the space culture. The regional centres exist to be reshaped to respond to national links through cooperation projects like the one effectively put into place by the Government of France. Once this is done, however, it is up to the scientific community in the sub-region to make use of the infrastructure and facilities.

NOTES

1. Lindenlaub, J.C. "Remote Sensing: What is it?" Fundamentals of Remote Sensing, minicourse study guide, Purdue University, USA, 1976.

2. Cracknell, A.P., Remote Sensing in Meteorology, Oceanography and Hydrology, Ellis Horwood, Ltd., England, 1983.

3. Konecny, G., "Mapping and Remote Sensing: Backbone of Environmental Information Systems in Africa," United Nations Regional Cartographic Conference for Africa, Adddis Ababa, 22-27 Feb. 1993.

4. ECA/CART, Country Reports to the Eighth United Nations Regional Cartographic Conference for Africa, Addis Ababa, Ethiopia, 22-27 Feb. 1993.

OTHER REFERENCES

1. Amamoo-Otchere, E. and G. Beaufils, Utilization of SPOT XS data for corridor definition of a proposed high voltage transmission line route in Nigeria, International Seminar on New Developments in Cartographic Applications of Remote Sensing, RECTAS, 30 Nov. - 5 Dec., 1992.

2. Holstein, L., Land Information Management: Issues and Opportunities in Developing Countries, GEOCARTO International, Vol. 8. 1. 1993.

A PRACTICAL APPROACH TO REMOTE SENSING FOR ENVIRONMENTAL MONITORING IN DEVELOPING COUNTRIES: BACKGROUND TO THE SAMOZ PROJECT IN MOZAMBIQUE*

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BACKGROUND

Presentation of new spatial data and the updating of existing information has traditionally been a time consuming and expensive task involving not only traditional field surveys and data collection, but also the costly technical processes of data compilation, map drawing, reproduction and printing. In many countries, large scale thematic maps do not cover the entire territory. If they do exist, the oldest of a series may be outdated in terms of contents when the suit is completed.

Advances in remote sensing and the application of photogrammetric methods have therefore made these methods into powerful tools for creating modern and accurate topographic maps in different scales, at least covering the most populated areas. Air photo-based remote sensing has also become an efficient tool for large scale thematic mapping of, for example, soils, geology, and vegetation, and in assessing land-capability and forest resources.

It is not surprising that enthusiasm and expectations were great during the initial phases of the development of satellite remote sensing. New technologies have opened promising perspectives into new and fascinating approaches to mapping and gathering environmental information. The digital approach, the wide perspective, the multispectral registrations, the repeated and continuous coverage promised an enormous technological potential.

After a long period (more than 20 years) of having access to sophisticated satellite remote sensing products and services it may now even be correct to talk of a mature technology, providing data of a high and reliable quality and where the distribution of data and various products usually runs smoothly. The progress in applied remote sensing in many developing countries has, however, found a surprisingly limited use in applied thematic mapping of natural resources and in base-line studies of the environment.

After many years of practical work as consultants in land and water development projects,

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* This paper, which was presented at the Third United Nations/Sweden Training Course on Remote Sensing Education for Educators, held at Stockholm and Kiruna, 3 May to 4 June 1993, does not necessarily reflect the views of the United Nations.

mainly in different African countries, we have to express a definite disappointment with the ways and pace at which satellite remote sensing has been introduced and applied in these countries. Before the turn of the century, a number of new and sophisticated sensor systems will be put in action and it is therefore time to assess how this potential has been, and should be, utilized with an emphasis on interpretation and presentation of findings for practical purposes.

LIMITATIONS AND POTENTIAL IN DEVELOPING COUNTRIES

During the initial phases of satellite remote sensing it was postulated, especially within the academic community, that the large quantities of data produced by the satellite sensors called for a computerized approach in both analyses of data and in the production of thematic maps for different purposes. Especially in the developing world, satellite remote sensing seemed to represent a possible short-cut in creating accurate and updated inventories of natural resources and environmental monitoring. Centres for digital data and image analysis were established in many countries, often tied to national mapping agencies, with the aim of supporting national natural resources inventories.

Analyzing a number of applied projects we have found, however, only a limited advancement of the digital image interpretation technique and associated production of thematic maps for practical purposes. The reason is not the technology as such, but the complexity of the object under study, the environment itself. Classification of data, application of statistical methods and perhaps a new colouring of the satellite scene can not produce a true and reliable thematic map, in spite of the fact that one of the popular satellite sensors is called "Thematic Mapper". In the best of cases, computer manipulation can enhance certain features in the satellite image by their disparate spectral signatures in order to help the analyst find and interpret what has been recorded by the sensor system. Other image properties which help us to detect and identify different features such as tonal changes and spatial arrangements are seldom accounted for.

One major factor behind this limited practical use may be a lack of balance between the push for computer-based, high-tech approaches and more appropriate low-tech methods. In a regional or national inventory, the digital approach can hardly be applied for thematic map production as the environmental variation calls for constant recalibrations of field data, within and between the satellite scenes, as well as between registrations from different seasons. We also have to realize that image interpretation experts do not really exist, but only experts on different subjects that are also good at image interpretation.

The over emphasis on computer-based handling of satellite data and the concentration of all resources and competence at single, national centres is likely to hinder or seriously delay the multitude of development work that is necessary to find suitable methods and approaches of applying the technology for practical purposes. According to the attitudes of many remote sensing specialists, the analysis of satellite data is a highly sophisticated technology that requires large and advanced computer resources.1/ As long as such attitudes prevail at national centres, the application of satellite information will hardly be transferred from the satellite data laboratory

to the users and clients at provincial or local levels.

Hopefully, the development will follow paths similar to the development of computing. At the dawn of the computer age only a few computer centres existed, managed by highly qualified technical specialist, while today personal computers have become useful in the everyday work of almost everyone in the industrialized world.

As we see it, to make effective and rewarding use of satellite remote sensing techniques in a developing country in the near future, the goal should be to introduce and apply methods that:

- can have an immediate impact;
- rapidly become operational;
- require only a short period of training;
- require limited investments; and
- can be applied not only on a central level but also regionally or even locally

In the future, people involved in applied remote sensing can look forward to a situation where satellite data is distributed in formats and on media that can be read and analyzed by low cost personal computers at provincial and local levels, i.e. where most of the practical work and field inventories are made. At present, however, we can easily distribute satellite data as images for use at those levels as it is possible to fulfil many of the requirements listed above if much of the same techniques and instrumentation that are used for studies of aerial photographs are also applied for the analysis of satellite images.

As aerial photos have for many years been used in all developing countries for topographic mapping, land-use and soil conservation planning, there exists a local competence in various aspects of aerial photo techniques. Most authorities and institutions working with aerial photos are usually well equipped with viewing equipment such as stereoscopes and stereo plotters and are therefore also well suited for the study of satellite images. If necessary, satellite data vendors can also tailor the images to meet the demands of individual clients, but still leave the interpretation of the images themselves to the real experts, the end users.

The training needed for satellite image analysis is mainly to familiarize local staff, most of whom possess a basic degree in their field of expertise, with the new types of images the satellite systems provide. These people are usually eager to absorb and utilize relevant parts of the new technology in order to solve problems they face in their everyday work. They are familiar with the region they are working in, its topography, geology, land use pattern, cultivation practices, and other factors that will be of great importance during the analyses of satellite images. This experience allows them to add a new dimension to planning and enables staff at the district, regional or central level to identify problems and potential solutions and to reach their own decisions on necessary actions to be taken.2/

Past experience of applied satellite remote sensing in developing countries has, according

to our view, so far confirmed that the visual interpretation of standard or enhanced image products is the most rewarding path to follow if the intention is to obtain appropriate results rapidly utilizing the local expertise involved in practical project work.3/

THE SAMOZ-PROJECT

Within the framework of the Southern African Development Coordination Conference (SADCC) a series of workshops have been organized in applied remote sensing.4/ It was proposed that the previously outlined approach to environmental monitoring projects be tested in Mozambique which is a SADCC member country with a high demand for new and updated environmental information because of the recent civil war that has obstructed conventional field studies for a long period of time.

Three environmental projects were selected by local authorities (See figure 1):

- Environmental impact assessment of the Pequeños Libombos reservoir near the capital city Maputo.
- Environmental impact on the coastal zone and upland areas (changes in forest vegetation by burning, depletion of mangrove recourse etc.) in the northern Cabo Delgado province.
- Conservation planning in the western province of Manica.

Different local organizations took responsibility for the individual projects. The Swedish Space Board has funded image acquisition and image tailoring and the Swedish International Development Authority (SIDA) has supported training and project work in Mozambique. The scientific support has been organized by the Research Programme on Applied Environmental Impact Assessment of Uppsala University and the image enhancement has been carried out in close cooperation between the Mozambique projects and Swedish Space Corporation.

The project commenced with a September 1991 workshop and field training course for the participants organized in cooperation with the local satellite remote sensing centre (CENACARTA). Further field training was organized in August 1992 in conjunction with a mid-term workshop reporting on current work and recent findings. Frequent field visits support the project and a newsletter is published in order to inform the participants about current activities.

From the start of the SAMOZ project, each local project was supplied with standard LANDSAT (MSS and TM) and/or SPOT (XS and P) im:.ge products and in one case also "split pixel" SPOT P images enlarged to working scales of 1:50,000 and 1:20,000 (see Appendix).

As of February 1993, image enhancement based on the Mozambique findings had begun and the first tailored imagery were expected to be tested in the field. One probable end product,

in combination with the design of a practical approach for Mozambique, is the publication of satellite image maps (i.e. enhanced images) corresponding to the national geodetic system for the topographical mapping. The maps will be printed in Mozambique and distributed to the projects for use in their continued work.

As the preliminary findings have been published as an extension to the regular SAMOZ newsletter, we will only present an outline of the current work and the approach under development.5/

THE APPROACH

The initiation of the project through an in-country training workshop enabled project participants to became accustomed to different kinds of satellite image products and interpretation techniques. In order to explore the range of possibilities and limitations with the available satellite material, a short field study was carried out within one of the project areas. As a result, follow-up programmes which outline participants respective projects could be defined.

Image material covering parts of the project area was used during the initial training and for the subsequent project work. The material initially tested included data from the following satellite sensors:

- LANDSAT MSS for monitoring catchment area land-cover changes and bush fires over time (1972 and onwards);
- LANDSAT TM and SPOT XS and P for monitoring and observing catchment environmental change, vegetation changes and conservation potential; and
- "Split pixel" SPOT P images for monitoring environmental changes to the riparian environment in the Umbeluzi Valley.

Image interpretation was conducted using available equipment such as lens or mirror stereoscopes to obtain stereo and bi-temporal views of each project area. The bi-temporal approach allows different image registrations to be viewed simultaneously and thus increases the quality of the analysis. As only small scale images can be conveniently used under a stereoscope, interpretations have been transferred to 1 cm by 1 cm grid overlays fitted to enlarged paper prints where each overlay has been related to geographical coordinates. The 1 cm by 1 cm square is then used as a base unit for image interpretation and classification.

The interpretation results have, in a numerical form, been stored in a spreadsheet programme (Excel) as SYLK-files. These analyses have been related to the needs of the different sub-projects such as land-cover, acreage of bush fires per season and year, soil-erosion, drainage etc. (i.e. land-cover class number, percent of area etc.). To produce overlay-maps and to compare interpretation results over time, a low cost raster-based GIS programme for the Macintosh computer programme, Map II, has been utilized. This has been one of the most promising results

so far of the project for analyses of findings and presentations at provincial and local levels. The user environment of the Macintosh has only required a limited amount of time and training in the use of the computer and the computer programme, enabling the end user to present his or her findings for rapid application in his day to day projects.

As the file format for data storage is universal, it can, at a later stage, be used for map compilation at a regional or national level by any geographical information system used. As the grid overlays are adjusted to geographical coordinates, a national centre will be able to easily compile results obtained at provincial or local levels and merge the data into a national data base.

The raster-based GIS programme has also made it possible to provide one sub-project with satellite data in digital form on HD diskettes. The same computer programme (Map II for the Macintosh computer) is used for the storage of interpretation data, in combination with visual interpretation of black and white images of the individual bands, and to define ranges of pixel reflectance values for the different environmental indicators which enables the end user to define the appropriate environmental indicators for his particular project. This information will be used in the tailoring of the final image product and is a further development of the practical approach, where the end user (at his field station) can define his or her needs to the image vendor in a more accurate form, maintaining control of image production and further image interpretation.

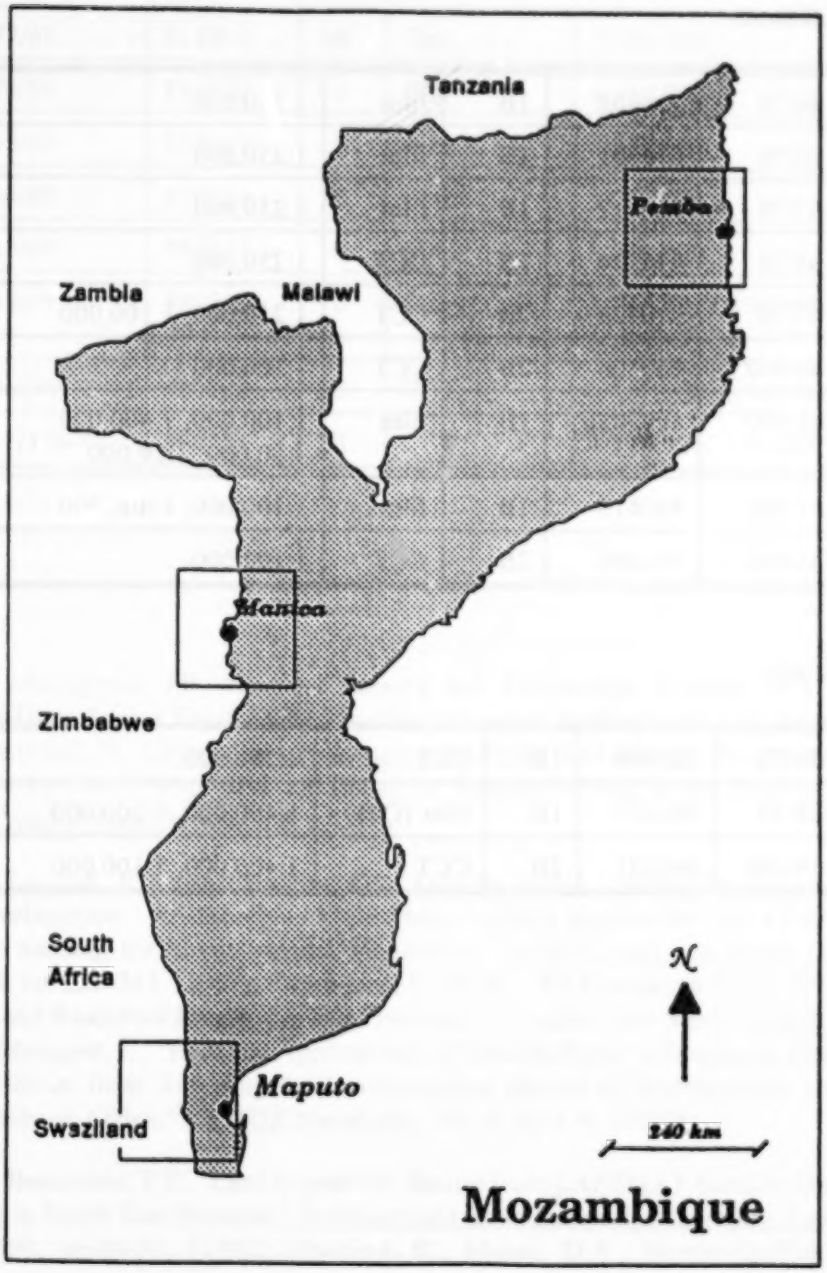
ACKNOWLEDGEMENTS

This project would never have been initiated without the enthusiastic support of Dr. Bernardo Ferraz of the Environmental Working Group in Mozambique and by Mr. Stigbjörn Olovsson of the Swedish Space Corporation. The latter has acted as a joint project leader together with Prof. Strömquist of Uppsala University.

The fatiguing task of collecting field information and interpretation of data has been carried out by several people in Mozambique. We would also like to specially mention Mr. Antonio Ferrao of the Forestry department in Pemba who, on his own, has developed methods to analyze and monitor forest change by burning, and Mr. Ebenizario Chonguiça of the Eduardo Mondlane University, who has inspired a group of geography students to obtain astounding results in image interpretation and evaluation.

The financial support of the Swedish Space Board and SIDA are gratefully acknowledged as is the work of Mr. Manuel Ferrao of CENACARTA in Mozambique, for supporting and taking part in the series of SAMOZ workshops.

FIGURE 1 - The three Mozambican project areas.



APPENDIX

The number of available satellite images within the SAMOZ project consists of the following:

Pequeños Libomos

MSS	180/78	720908	1B	film	1:250,000
MSS	180/78	810801	1B	film	1:250,000
MSS	167/78	890717	1B	film	1:250,000
MSS	168/78	890724	1B	CCT	1:250,000
TM	167/78	910723	2B	CCT	1:250,000, 1:100,000
XS	140/402	860526	2B	CCT	1:100,000
PAN	141/402	8607626	1B	film	1:100,000, 1:400,000 1:50,000, 1:20,000
XS	141/402	880613	1B	film	1:100,000, 1:400,000
XS	141/402	910406	2B	CCT	1:100,000

Manica/Chimoio

MSS	180/73	720908	1B	CCT	1:250,000
TM	168/73	901015	1B	film (Q3)	1:400,000, 1:100,000
XS	139/388	860621	2B	CCT	1:400,000, 1:100,000

Cabo Delgado

MSS	177/69	810623	1B	film	1:250,000
MSS	177/69	810921	1B	film	1:250,000
MSS	177/69	811009	1B	film	1:250,000
MSS	176/69	810920	1B	film	1:250,000
MSS	165/69	841001	1B	film	1:250,000
MSS	165/69	870916	1B	film	1:250,000
MSS	165/69	880817	1B	film	1:250,000
TM	164/69	890509	1B	film (Q1,3)	1:250,00, 1:100,000 1:50,000
XS	151/374	920702	2B	CCT	1:100,000, 1:50,000
XS	151/374-75	860713	2B	CCT	1:100,000, 1:50,000

NOTES

1. Malingreau, J.P., "Remote Sensing and Technology Transfer in a Developing Society - Or Is There Such a Thing As Appropriate Advanced Technology?" ITC Journal, 1981-2, pp. 125-139; Mitchell, B., Geography and Resource Analysis, (2nd edition), Singapore, 1989; and Parry, J.T., "Background, Perspective and Issues for Remote Sensing in the Tropics," in Remote Sensing and Tropical Land Management, 1986.

2. Larsson, R.A., and Hanson, G., "Applied Visual Landsat Inventories for Water Resources Development: An Ethiopian Case Study," UNGI Report, No. 61, (1985); Larsson, R.A., "Remote Sensing for Environmental Monitoring," SADCC Soil and Water Conservation Report, No. 13, pp. 226-243, (1987); Strömquist, L., et. al., "An Evaluation of the SPOT Imagery Potential for Land Resources Inventories and Planning, A Lesotho Case Study, UNGI Report, No. 68, (1988); Strömquist, L., "Practical Applications of Satellite Remote Sensing in Environmental Studies, Experiences from Assessing the Environmental Impact of Hydrodpower Development Projects in Southern Africa," SAMOZ Newsletter, No. 5, pp.1-4, (1992).

3. Beaumont, T.E., "Land Capability Studies from LANDSAT Satellite Data for Rural Road Planning in North East Somalia," Transport and Road Research Laboratory Supplementary Report, No. 690, pp.86-91, (1982); Dunford, C., Mouat, D.A., Norton-Griffiths, M., and

Slaymaker, D.M., "Remote Sensing for Rural Development Planning in Africa," ITC Journal, pp. 99-108, (1983); Haack, B., "A Comparison of Visual and Numerical Analyses of LANDSAT Data for Grassland and Forest Inventories in Swaziland," ITC Journal, No. 1, pp. 6-12, (1983); King, R.B., "Rapid Rural Appraisal with LANDSAT Imagery: a Tanzanian Experience, Zeitschrift für Geomorphologie, Suppl. Bd. 44, pp. 5-20, (1982); Larsson, R.A., and Hanson, G., op. cit., (1985); Larsson, R.A., and Strömquist, L., "A Practical Approach to Satellite Image Analysis for Environmental Monitoring," SADCC Environmental Monitoring Systems, Vol. 1, (1991); Zietsman, H.L., "Land Use Mapping of the South Western Cape with the Use of LANDSAT Data," presented at the Symposium on Pattern Recognition in Remote Sensing and Geophysics, University of Witvatersrand, (1984).

4. Larsson, R.A. and Strömquist, L., op. cit., (1991); and Larsson, R.A. and Strömquist, L., "Air-Photo Analysis for Environmental Monitoring in the SADCC Region," SADCC Environmental Monitoring Systems, vol. 2. (1991).

5. All in SAMOZ Newsletter, No. 5, (1992); Chonguiça, E., "Síntese da avaliçao da aplicabilidade das imagens satélite e fotografias aéreas no domínio dos estudos ambientias, Estud de caso aplicado ao nível da bacia do Umbeluzi," pp. 11-13; Monjane, M., "Preparaçao do mapa de regimes floresta e inventário de biomass lenhosa," pp. 26-32; Manyatsi, A.M., "Application of Satellite Remote Sensing for Land Cover Classification in Swaziland," pp. 35-36; Mushala, H.M., "A Practical Approach to Visual Image Interpretation in Remote Sensing for Natural Resources Survey, pp. 34-41; Rydén, A., "Interpretation Elements in Environmental Survey," pp. 23-26; Strömquist, L., "Practical Applications of Satellite Remote Sensing in Environmental Studies, Experiences from Assessing the Environmental Impacts of Hydropower Development Projects in Southern Africa," pp. 1-4; Tantham, S., "Satellite Image Data as an Information Source for Screening Environmental Impacts," pp. 15-22.

ON WOLF-RAYET STARS*

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INTRODUCTION

The purpose of this presentation is to review the nature of Wolf-Rayet (WR) stars and their galactic distribution. Although the number of WR stars is small,1/ their modifying power on the interstellar medium is large.2/

The following summary is based on the treatises collected up until 1990 and several more recent technical reviews.3/ Some of them are incorporated here for the purpose of completeness.

INVENTORY

There are now 172 known WR stars known in the Galaxy, 115 in the Large Magellanic Cloud (LMC), eight in the Small Magellanic Cloud (SMC), and many more are becoming visible in other Local Group of galaxies and beyond. The galactic WR stars have been subclassified in 91 stars of the WN sequence (dominated by nitrogen and helium lines), 73 stars of the WC sequence (dominated by carbon and helium lines), six WN/WC stars (intermediate type) and two stars of the WO sequence (dominated by oxygen and helium lines). A new topic of the past decade has arisen from the numerous discoveries of extragalactic WR stars. Only in Local Group galaxies can WR stars be studied individually. In more remote galaxies, primarily irregular dwarf galaxies, and blue compact emission line galaxies, this is more problematic. Integral WR features are found to be sometimes grouped into individual (giant) H*II* regions. The inferred numbers of WR stars they seem to contain are based on, given the distance of a galaxy, the amount energy in its He*II* 4686 emission line compared to that of a single WR star.

BASIC PARAMETERS AND GALACTIC DISTRIBUTION OF WOLF-RAYET STARS

Intrinsic parameters of WR stars, such as intrinsic colours, colour excesses and absolute visual magnitudes, have been extensively reviewed by K.A. van der Hucht. The many extensive data sets available in the literature allow one to derive these parameters, and to determine photometric distances with an accuracy of about 50 per cent. Studies of the galactic distribution of WR stars as a diagnostic tool for the determination of their evolution and initial masses (M)

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provide good agreement between observation and theory. The concentration of WR stars in a galactic spiral arm and their absence toward the galactic anti-centre (Orion spur), known since the pioneering work of the early 1960s, and the concentration of late-WC stars toward the galactic centre, also known since the late 1960s, has been confirmed by more recent studies.

BINARY WOLF-RAYET STARS

After the numerous determinations of WR binary orbital solutions in the early 1980s, the main breakthrough has been the determination of orbital inclination from linear polarization modulation measurements, notably by Moffat and his associates at Montreal University in Canada. Resulting masses range from 6 to 40 solar masses (M_O) for *WN* stars and from 5 to 20 M_O for *WC* stars in binaries in the Galaxy and in the Large Magellanic Clouds.

It is well possible that some WR stars are accompanied by a compact companion left over after a supernova explosion of the primary. The number of candidates has dwindled somewhat in the past decade where the interest has drifted from compact companions to intrinsic variability. Among the dozen or so candidates left, the two most likely candidates are HD 50896, a *WN5* star orbiting a neutron star in a period of 3,76*d*, and HD 197406, a WN7 star orbiting a black hole in a period of 4,32 *d*. While for most stellar types the binary frequency is about 50 per cent, WR binaries are harder to detect and therefore the frequency of known binaries in the solar neighborhood is about 40 per cent to date. A fascinating but time consuming way of detecting binaries has been discovered by Perry Williams of the Royal Observatory Edinburg (United Kingdom) in the case of long period (P - 10 *yr*) eccentric WC binaries, where periodic dust formation may occur, as is the case for HD 193793 and at least three more WC stars. Such binaries can also be discovered as strong X-ray and non-thermal radio sources, the emissions of which are believed to be associated with their colliding winds.

All these binary aspects were impressively reviewed by Anatol Cherespaschuk of Stenberg Astronomical Institute in Moscow, Russian Federation.

MASS LOSS OF WOLF-RAYET STARS

Wind characteristic and mass loss rates of WR stars have been reviewed by Allan Willis of University College London. Mass loss rates can be determined for many *WR* stars (i) from their infrared and radio free-free emission, giving density in the winds; (ii) from their ultraviolet P-Cygni profiles, giving their wind terminal velocities; and (iii) from their distances, when applying the theory of spherically symmetric mass loss. In recent years such determinations have been affected by: (i) increasing knowledge of abundances and ionization degree and ionization structure; (ii) realization of the true nature of P-Cygni profiles; and (iii) improved knowledge of photometric distances. Taking all those effects into account Raman Prinja, Ian Howarth and Mike Barlow of University College London (United Kingdom) find mass loss (*M*) for WR stars in the range of:

$$M = [2\text{-}10]\times10^{-5}\ M_O yr^{-1}.$$

It is possible to find the mass loss rate of a WR binary in an independent way by monitoring its period change. This method has already been developed and was applied in 1974 to V444 Cyg (WN5+06) by Kh.F.Khaliullin of the Stenberg Astronomical Institute, who has since improved this method. The result agrees within a factor of two with the method mentioned above.

WR stars have the largest continuous mass loss rates of all stellar cases. This huge mass loss rate can be at least partly attributed to radiation pressure, but additional mechanisms seem necessary to explain its magnitude. Possible ways out have been reviewed by Joe Cassinelli of Washburn Observatory in Wisconsin, United States, involving effects of rotation, differences in equatorial and polar overflows and open magnetic fields, or alternately more extreme radiation pressure induced by higher effective temperatures.

ENRICHMENT OF THE INTERSTELLAR MEDIUM BY WOLF-RAYET STARS

WR stars emit huge amounts of gas and energy into the interstellar medium, a topic reviewed by Martin Cohen of the National Aeronautic and Space Administration's Ames Research Center, California, United States. During its lifetime a WR star emits an amount of energy comparable to that released by a supernova event. Although within 3 *kpc* from the Sun, WR stars comprise less than 5 per cent of the total number of early-type stars having stellar winds (B- and A-type supergiants, O-type stars and WR stars), WR stars provide more than half of the mass and wind energy input into the interstellar medium.

Infrared photometric studies of WR stars since 1972 have demonstrated that most late-type WC stars (85% of the WC9 stars and 50% of the WC8 stars) are surrounded by heated dust (T_d = 1300K). Evidence indicates that this circumstellar dust is amorphous carbon (soot), which is being formed continuously within their stellar winds at typical radii of - 350 R for WC 9 stars and - 800 R_* for WC8 stars, because of a combination of high carbon abundance and high gas pressure. Also a few WC7 stars show dust formation, but only episodically. One of those, HD 193793, happens to be a WC7+04 binary with a period of 7.94 years and a very eccentric orbit, where dust formation is occurring during a few months around periastron passage. March 1993 was the last occasion of dust formation around this binary, which was visible by a sudden increase in brightness of about 2.5 *magnitude* at near-IR wavelengths.

The formation of amorphous carbon in the winds of late-type WC stars is a clear indication of the larger-than-cosmic carbon abundance of WC stars, and can directly be compared to cases of carbon dust formation in other evolved objects, like novae.

Some 10 per cent of the known galactic and LMC WR stars are surrounded by nebulae, more often called ring nebulae, (semi-)spherical H *II* regions with radii of the order of parsecs, which are a manifestation of past mass release of their central stars, be it by steady wind or episodic events. Reviewed by You-Hua Chu of the University of Illinois, United States, WR ring nebulae have been classified morphologically as stellar wind blown bubbles, stellar ejecta, and

shell structured H *II* regions. It is quite possible that at least the ejecta-type WR ring nebulae were created during a pre-WR phase.

Matter in WR ring nebulae can be a combination of (pre-WR) stellar wind c.q. ejecta and swept-up interstellar matter. WR ring nebulae are chemically in helium and nitrogen, revealing the larger-than-cosmic abundances of the (pre-)WR wind and ejecta. Observed ionization ratios in the nebulae yield effective temperatures for the central stars, which are in good agreement with those found by comparing WR spectra with model atmospheres.

Because of their production of heavy elements, WR stars may to a certain degree be responsible for anomalous *C, Ne,* and *Mg* isotope ratios found in cosmic rays and certain meteorites. The importance of a possible WR contribution to the amount of $^{26}_{Al}$ near the galactic centre, derived from the intensity of the observed 1.81 *MeV* γ-ray emission observed in that direction, is still a matter of debate.

NOTES

1. Hidayat, B., Admiranto, A.G., and van der Hucht, K.A., Astrophysics, 99, 175, 1984; Admiranto, A.G., Hidayat, B., Supelli, K.R., and van der Hucht, K.A., Astrophysics, 199, 217, 1988.

2. Cohen, M., in K.A. van der Hucht and B. Hidayat (eds.), Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies, 1991.

3. Hidayat, B. and van der Hucht, k.a., (eds.) Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies, Kluwer Academic Publishers, Netherlands, 1991.

BASIC SPACE SCIENCE IN AFRICA*

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INTRODUCTION

The impact of space science and technology on mankind has been phenomenal over the last four decades. The achievements of space technology have provided an effective tool for the investigation of many new branches of basic space science research related to astronomy, cosmology, solar-terrestrial physics, upper atmosphere-ionospheric physics and the science of the Earth's environment.

The United Nations as well as other international organizations are currently alarmed about the way in which the world's developing countries are being left behind in the development of space science and its applications. While some countries such as China and India have made considerable progress and have achieved the capability to design and develop satellites, launch vehicles, balloon-borne and rocket-borne instruments, as well as to conduct observational research in astrophysics, basic space science is almost non-existent in most African countries.

Since 1991 the United Nations has intensified its efforts to find ways and means of introducing basic space research in Africa as well to improve the situation in other more advanced developing countries such as China and India. International workshops on space science are one vehicle the United Nations is utilizing to tackle the problem.

Space scientists have recognized that their field is an international enterprise. Global joint observations and multilateral collaboration are indispensable for both ground-based and space-based astronomical research. Examples of successful international cooperation in astronomy include the GONG project for studying the motions of the solar surface, the Solar-A and IRAS satellites, the International Radio Interferometer, and the International Ultraviolet Explorer, etc. Therefore, success in astronomy and other areas of space science is best achieved through international collaboration, which indirectly benefits the development of human resources. If African countries are to catch up with the developed world in space science, it is vital that they become involved in such collaborative efforts.

THE PRESENT STATUS OF BASIC SPACE SCIENCE RESEARCH IN AFRICA

In order to obtain information about scientists who are already conducting research in basic space science in Africa, questionnaires were sent to institutions in about 30 African countries. South Africa was excluded since it is known to be fully developed in space

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science, particularly in astronomy and astrophysics.

A list of topics in space science was included in the questionnaire and the responding scientists were asked to indicate the elements of space science that he or she was involved in. The topics included: observational astronomy, theoretical astronomy and astrophysics, cosmic rays, cosmology, gravitation, geomagnetism, ionospheric physics, meteorology, remote sensing, satellite communications, and others.

Replies were received from Egypt (space geodesy and satellite observations); Congo (atmospheric physics); Kenya (astrophysics and remote sensing); Liberia (ionospheric physics); Malawi (satellite communications), and Nigeria (astrophysics, cosmology, atmospheric physics, meteorology, remote sensing, geomagnetism, and satellite communications). In addition, space scientists have been identified in Morocco (astronomy, meteorology) and there are also a large number of astronomers in Egypt.

As researchers know, response to questionnaires is often poor. However, it is clear that most of Africa has been untouched by space science. Also worrying is that even the research which is being conducted in Africa is largely theoretical.

EFFORTS BEING MADE AT THE UNIVERSITY OF NIGERIA, NSUKKA

Since 1980, the Space Research Centre at the University of Nigeria has made efforts, within its limited resources, to put Nigeria on the space research map.

On the theoretical side, the Space Research Group has cooperated with other colleagues in the world in the areas of high energy astrophysics, and cosmology. The International Astronomical Union, the International Centre for Theoretical physics, and other international organizations have provided support to keep the research library of the Space Research Centre up-to-date with important journals in these research areas at no cost to the Centre. Support has also been provided for members of the group to attend international workshops and conferences, which are so important for stimulating research. In addition, many observatories all over the world provide preprints of their research work to the Centre on a regular basis. Evidence of the research work done can be seen in the number of publications in international journals of astronomy and astrophysics. More than 50 theoretical papers have been published in international journals by members of the Space Research Group over the past decade. Additionally, seven Ph.D's and more than 20 M.Sc's have been successfully completed in astrophysics and cosmology.

The Space Research Centre cannot, however, continue to depend only on theoretical work to make a mark in the international space community. Actual observational and experimental work is also necessary. In this regard, the Space Research Centre has taken several steps to start this process.

A successful attempt was made to acquire and install a 10 m satellite dish in 1984, but this dish has not been made functional due to lack of funds to construct the receiver system and control units, and problems of continuing with such an expensive project without major funding. Because of this, the two station observations planned to take place between Nigeria and Germany (VLBI) and Nigeria and India (scintillation of pulsars) could not take place as

planned. The telescope by itself cannot be used for any front-line research because of its small collecting area. Therefore it was decided to temporarily suspend the project.

In 1980 the Space Research Centre also initiated a plan to establish a giant equatorial radio telescope (GERT) as a collaborative effort between India, Indonesia, Kenya, and Nigeria. Unfortunately, this appeared to be a too ambitious project to start with at that time, and the possible site for locating the telescope was never successfully resolved. Ultimately, the project had to be dropped.

The Space Research Centre at the University of Nigeria, Nsukka, has been making an effort to find a suitable frontline, less expensive and almost independent space research project that would fully utilize its accumulated experiences. At this time it may have eventually hit the right path to follow. This is the new technology of solar seismology, a very advanced and highly rewarding project which is unique in the world. The University of Nigeria, Nsukka-based instrument will, when completed, make independent observations and collect and analyze data which complements similar stations in the United States, Russia and China.

THE PROPOSED INTERNATIONAL GROUND-BASED OBSERVATION PROGRAMME ON SOLAR SEISMOLOGY

The project involves the fabrication and installation of a computerized optical telescope for detailed solar seismology studies, new technology which has the potential for frontline research. The institutions and countries participating in the project will be involved in the development process. Scientists and technical staff from the University of Nigeria will be involved in the design and construction of the system in Arizona, United States and the system will then be installed in Nigeria.

This project has received the approval of the University of Nigeria, Nigeria's National Committee on Space Policy, the Government of Nigeria and the National Agency for Science and Engineering Infrastructure. Feasibility studies for site selection were initiated in March, 1992.

The four primary objectives of the project are:

a) to develop an international network of highly advanced astrometric and photometric solar seismographs for the study of long-term solar variability and the internal structure of the Sun. By having observatories spaced around the world, it is hoped that the Sun will be observed on a 24-hour basis;

b) to contribute to a more effective and comprehensive approach to global resources management by pushing out the limits of our current understanding of solar energy output and its impact on our climate;

c) to provide a stimulating learning environment at the leading edge of physics and astrophysics for undergraduate and graduate students; and

d) to advance cooperation, understanding and security at the international level through pursuit of research activities involving the exchange of data, students and researchers

between China, Nigeria, the Russian Federation and the United States.

Clearly, such a project is very suitable for a country like Nigeria which is trying to get involved in space science. The instrument is small, low-cost, yet powerful and technologically advanced. Researchers are likely to be able to contribute to some very significant problems in astrophysics, for example the solar neutrino paradox in which the observed solar neutrino flux is significantly lower than expected. Insight may also be obtained into the primordial helium abundance, the number of neutrino families and the validity of the Big Bang theory of the early phase of the universe. Also, the study will lead to information about the internal rotation of the Sun which is related to studies of magnetic field generation in stars and testing theories of gravitation. Other important research areas likely to benefit from this work include the theory of convection, the stability of stratified systems and the existence of weakly interacting massive particles.

Apart from the purely scientific aspects of the project, there are likely to many spin-offs in terms, of technical, mathematical and computer competence and in terms of environmental factors and resources management. Considerable potential exists for further development of applications of the technology used in the project.

PROBLEMS FACING THE DEVELOPMENT OF SPACE RESEARCH IN AFRICAN COUNTRIES

One major problem of space science in Africa is the lack of a space science culture. To many policy decision makers it appears that space research has no immediate value to the majority of the poor population. It is therefore necessary to stimulate the interest of governments to the realities and benefits of the space era. This is one of the many aims of workshops such as this one. In addition, space science needs to be included in the educational programmes of African countries at all levels. Programmes to popularize space science are also needed to develop awareness in the general population.

Another major problem is of course one of cost. Most space science projects appear to be very expensive and technically demanding. This is why cost-effective projects, such as the solar seismology project described here must be found in which African scientists and technologists fully participate in the development and running of the project. International collaboration and linkage programmes with developed countries are really the only way forward for African countries. In this way costs can be shared and technical expertise gained.

An immediate problem which is intimately linked with space science is that of the lack of a reliable and effective communication system in many African countries. Not only do telecommunications depend on much of the technology developed from space science, but it is vital that good communications are available if any meaningful collaborative work is to be conducted. This problem needs to be tackled immediately, with the aid of international agencies if necessary.

CONCLUSION

It is clear that African countries are lagging far behind the developed world in the area of space science. Progress in space science research in many developing countries is likely

to mainly depend on the kind of assistance received from developed countries.

Developing countries need help in acquiring suitable modern instrumentation and data processing facilities as well as assistance in making such equipment operational. Short-term fellowships, travel support and assistance to participate in international meetings are needed to encourage scientists from developing countries. Above all, policy makers in developing countries need to be educated and made aware of the importance of space science and its various technological spin-offs. Scientists in Africa must have the support of their governments to make any meaningful headway in the development of space science.